AGGREGATE SAMPLING AND TESTING
FOR
TRANSPORTATION ENGINEERING TECHNICIANS

PREFACE

Portions of the New England Transportation Certification Program (NETTCP) “Soils & Aggregate Technician Certification Manual Version 1.5" as copyrighted in 1996 by the New England transportation Technician Certification Program, Inc. were excerpted or used in the preparation of this material with their permission.

The material presented was developed by the FHWA Aggregate Training and Certification Group which included representation from the NETTCP. Representation on the group included industry, State DOT technicians, training program coordinators, laboratory and quality assurance personnel as listed below.

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BACKGROUND

The Code of Federal Regulations, Part 637, requires all personnel performing sampling and testing that will be included in acceptance decisions to be “qualified” after June 29, 2000. This means that before this date, each state highway department must have an approved program in place to evaluate individuals who will perform such sampling and testing. This manual has been created to aid those agencies that may not have an existing training and qualification program in place for testing technicians. The material may also be of benefit to those agencies that are reviewing their existing programs or that may be in the initial stages of reciprocal program development with other agencies. The training materials are designed to provide the candidate technicians with clear instructions in the performance of the individual test methods included, sample calculation examples where applicable, and sources of common errors in running the tests.

This training material is designed to assist training personnel, highway engineers, and technicians in presenting the material to achieve the goal of technician qualification status. The material

should be presented as a combination of instruction, demonstration, and hands-on practice. Written exams and performance evaluations should not be administered until the candidate technician has had adequate time for mastering performance of the applicable tests. The sections of the test method units include a QUIZ or series of questions/calculations that may be of use in the preparation of a written examination coverage of the test method or during instruction in the test method procedures. It should be noted, however, that development of a database of questions for use in the examination of technician candidates will be needed and should be used for random selection of questions for each examination. The questions provided are examples dealing with the basic knowledge of the test method, and not meant to be the sole source of questions that would be used.

The material provided is specific to AASHTO sampling and testing methods, except where AASHTO has adopted the equivalent ASTM test method. If used in a conscientious manner, this material should meet FHWA requirements for satisfaction of the requirements for aggregate technician qualification.

RECIPROCITY

It is recommended that states teach these basic AASHTO/ASTM procedures first, supplementing the standard materials tests with the state policies and unique procedures. Trainees would then be qualified for the AASHTO/ASTM procedures, enabling them to present their credentials for reciprocal qualification in other states.

TEST METHODS

The individual procedures included in this manual were selected by representatives of state highway agencies, the FHWA, academia, contractors, and national transportation industry associations at the 1997 Multi-regional Training and Certification Conference held in Arlington, VA. The test methods (AASHTO and ASTM) selected were based on the knowledge of the conference attendees and their experience in testing requirements common to the transportation industry. The use of these test procedures and the training material included will support the possibility of reciprocity of testing technician personnel qualification programs in different state highway agencies. State agencies are free to use these materials as they wish. They can be used as presented, modified to match an agency's testing procedures, expanded to include state specifications, sampling procedures, documentation, etc. The test methods covered in the manual represent inclusion of aggregate tests necessary for general aggregate use requirements and also testing for use in asphaltic concrete and portland cement concrete.

The test methods presented include the following:

AASHTO T2	-	Sampling of Aggregates
ASTM D3665	-	Random Sampling of Construction Materials
AASHTO T248	-	Reducing Samples of Aggregate to Testing Size
AASHTO T255	-	Total Moisture Content of Aggregate by Drying

AASHTO T27	-	Sieve Analysis of fine and Coarse Aggregates
AASHTO T11	-	Materials Finer Than 75 μm (No. 200) Sieve in Mineral Aggregates by Washing
AASHTO T96	-	Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C535	-	Resistance to Degradation of Large Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
AASHTO T112	-	Clay Lumps and Friable Particles in Aggregate
AASHTO T176	-	Plastic Fines in Graded Aggregate and Soils by Use of The Sand Equivalent Test
AASHTO T85	-	Specific Gravity of Coarse Aggregate
AASHTO T84	-	Specific Gravity of Fine Aggregates
AASHTO T19	-	Unit Weight and Voids in Aggregate
AASHTO T21	-	Organic Impurities in fine Aggregates for Concrete (Color Plate Test)
AASHTO T113	-	Lightweight Pieces in Aggregate
AASHTO T104	-	Sodium Sulfate Soundness
ASTM D5821	-	Determining Percent of Fractured Particles in Coarse Aggregate
ASTM D4791	-	Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
AASHTO T304	-	Uncompacted Void Content of Fine Aggregate

Inclusion of the AASHTO or ASTM Standard Test Methods with the training material is strongly suggested as a reference for the student. The test method procedures are in accordance with the standards, but are presented in language to simplify training and accomplishment of the test procedures.

GENERAL COMMENTS

The training prerequisites related to individual test methods, where listed in the test method, are recommendations and may be changed by the user.

The “NOTES” provided in the test method training material are for use by the training instructors or may be left in place for student information. Glossary items may not be complete dependent upon the terminology used in individual states. The glossary definitions provided may need supplemental information depending on the circumstances of each state/industry terminology for establishment of a common language relevant to the applicable specifications.

Students are to use the mathematical rounding rules for each state agency in performing calculations for qualification testing. The rounding procedures used in this manual may not reflect the same rounding procedures used in individual states.

Each state should use its own standard forms for the documentation of test results. No project referenced forms are provided with these test methods.

SAMPLING OF AGGREGATES

AASHTO T 2

Developed by
FHWA Multi-Regional Aggregate Training & Certification Group
1999

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NOTE

AASHTO T 2 is identical to
ASTM D 75.
All references to ASTM C 702
contained in ASTM D 75
shall be replaced with AASHTO T 248.

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- ASTM D 3665, Practice for Random Sampling of Construction Materials

GLOSSARY

Field Sample - a quantity of the material to be tested of sufficient size to provide an acceptable estimate of the average quality of a unit.

Lot - a sizeable isolated quantity of bulk material from a single source, assumed to have been produced by the same process.

Test Portion - a quantity of the material of sufficient size, extracted from the field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

Unit - a batch or finite subdivision of a lot of bulk material (for example, a truck load, a specific area covered, or a certain amount of tons produced.

SAMPLING OF AGGREGATES

Aggregates are the main ingredient in most highway construction. They are used in all phases from base construction, pavement mixes, granular shoulders, granular surfacing, and erosion control. For aggregates to perform as intended, they must meet certain physical requirements such as proper gradation, durability to resist the effects of weathering and resistant to abrasion loss.

The most important phase of an aggregate inspector's duties is securing a representative sample. At this point, all the money and time which will be expended on the remaining activities of testing and evaluation may be lost or rendered useless by an improper sampling technique. In other words, if the samples taken are not representative of the total material, it is impossible to end up with meaningful test results. At the completion of this instruction, the technician must know how to obtain a proper sample. Without this knowledge, it is useless to proceed further into the areas of the test procedures.

Test samples should represent the total amount of the material being produced or used. This is normally accomplished by random sampling. All material should have an equal chance of being tested. Random samples are taken when the plant or operation is continuing at the usual rate. During production at the source, care must be taken to ensure the virgin material being processed is normal to the overall consistency of the available material. Clay pockets, boulders or varying seams in a gravel pit, mine, or quarry may create short-term variations in the consistency of the product.

It must be pointed out that not all samples are random samples. At times the inspector must choose the time of sampling, especially during the production phase. Control samples may be needed during start-up, equipment changes or changes in the virgin material. These circumstances will directly affect the gradation of the material and must be checked to keep the material within proper limits. During a normal day's operation, all samples taken may be random samples if all operations are running consistently. Some days may have no random samples taken, such as the first days run to establish crusher settings, etc. Some days will have a combination of random and control check samples. The inspector should not determine when or what to sample by judging if the materials looks good, bad, or average, because that represents a judgement sample and not a random sample.

Keep in mind that during normal, steady operations the samples should be selected in a random method such as described in ASTM Practice D 3665.

When securing processed aggregate samples, at least three increments of course aggregate shall be taken by an appropriate method as described in this instruction. There should be five increments of fine aggregate sampled using the sampling tube. More increments may, and when practicable, should be taken to build the field sample. Taking more increments is getting a better cross-section of the total material.

The discussion of securing samples would not be complete without mentioning safety. The production and placement of aggregates during use requires the use of heavy equipment and large bins. The conditions are frequently dusty and noisy. The aggregate technician must use extreme caution and ensure themselves that sampling locations are safe.

SUMMARY OF AGGREGATE SAMPLING

There are four methods approved by AASHTO for securing aggregate samples. The method the technician uses depends on the type of aggregate they are sampling, the location of the sample, and the equipment available at the sampling location. The four methods include:

- **Flowing Aggregate Stream (Bins or Belt Discharge)**
- **Conveyor Belt**
- **Stockpiles or Transportation Units**
- **Roadway (Bases and Subbases)**

The most accurate way to ensure that aggregate, as produced, meets the requirements would be to test the entire stockpile. This would not only be impractical, but virtually impossible. Accurate, representative samples must be secured for testing to ensure the required characteristics are met.

Aggregate samples may be obtained at different stages of production or construction:

- **Preliminary source investigation to determine potential. These samples are normally obtained by the party responsible for development of the source.**
- **During aggregate production at the source, samples of materials for control of the production at the source are obtained by the manufacturer, contractor or other parties responsible for the work such as private consultants.**
- **Control of the operations at the jobsite is also the responsibility of the producer, contractor or other qualified parties.**
- **Samples to determine acceptance or rejection by the purchaser are obtained by the purchaser or an authorized representative.**

Samples secured for the purpose of quality testing such as soundness, clay content, resistance to abrasion, etc., should be obtained from the finished product when practicable. Samples from the finished product to be tested for resistance to abrasion shall not be subject to further crushing or manual reduction in particle size unless the size of the finished product is such that it requires further reduction for testing purposes.

COMMON TESTING ERRORS

- **Using improper sampling device.**
- **Sampling in segregated areas.**
- **Not obtaining enough increments.**
- **Improper sampling method for particular aggregate.**
- **Allowing overflowing in a streamflow device.**

NUMBER AND MASS OF FIELD SAMPLES

The number of field samples required depends on how critical and variable the properties are to be tested. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples during production must be sufficient to give the desired confidence in the test results. The amount of material to be represented by a single field sample should neither be so large as to mask the effects of significant variability within the unit nor so small as to be effected by the inherent variability between small portions of any bulk material.

Field sample masses must be based on the type and number of tests to be run on the aggregate. Standard acceptance and control tests are covered by AASHTO/ASTM standards and specify the portion of the field sample required for each specific test. Generally speaking, the masses shown in the following table will provide sufficient material for routine grading and quality analysis. Extract test portions from the field sample according to AASHTO Designation T 248.

Nominal Maximum Size of Aggregates*	Appropriate Minimum Mass of Field Samples, kg (lb.)**
Fine Aggregates	
2.36 mm (No. 8)	10 (25)
4.75 mm (No. 4)	10 (25)
Coarse Aggregates	
9.5 mm (⅜ in.)	10 (25)
12.5 mm (½ in.)	15 (35)
19.0 mm (¾ in.)	25 (55)
25.0 mm (1 in.)	50 (110)
37.5 mm (1½ in.)	75 (165)
63 mm (2 in.)	110 (220)
50 mm (2½ in.)	125 (275)
75 mm (3 in.)	150 (330)
90 mm (3½ in.)	175 (385)

**** For processed aggregate the nominal maximum size of particles is the largest sieve size listed in the applicable specification, upon which any material is permitted to be retained.***

***** For combined coarse and fine aggregates, minimum mass shall be equal to the coarse aggregate minimum plus 10 kg (25 lb.).***

SHIPPING SAMPLES

Transport aggregate samples in bags made for that purpose or other suitable containers so constructed as to prevent loss or contamination of any part of the sample, or damage to the contents from handling during shipping.

The sample containers shall have suitable individual identification attached and enclosed so the field reporting, laboratory logging, and test reporting may be facilitated.

SAMPLING METHODOLOGY - AGGREGATE STREAMFLOW

Before taking a sample, you must first assemble all the equipment you will need to obtain the sample. To obtain a sample using the aggregate streamflow, you will need the following:

- **Sampling device designed for use at each particular plant. This device consists of a pan of sufficient size to intercept the entire cross section of the discharge stream and retain the required quantity of material without overflowing. In some situations, a set of rails may be necessary to support the pan as it is passed through the streamflow.**
- **Safety equipment such as hard hat, glasses, etc.**
- **Sample containers, tags, etc.**

Sampling Procedure

Pass the sampling device through the streamflow, being sure to cut through the entire cross section of the material as it is being discharged. Care must be taken to pass the device through the stream rapidly enough to prevent any overflow of material during the sampling procedure. Obtain a minimum of three increments for each sample. Be sure to obtain equal increments. Obtain the appropriate mass to accommodate all tests to be performed on the sample. Allow an amount of time to elapse between passes to better get a representative sample of the material. When sampling aggregate from a loaded bin, increments should not be obtained when the belt first starts or when the bin is nearly empty to avoid the natural segregation that may occur as the material exits the bin.

Streamflow Sampling

SAMPLING METHODOLOGY - CONVEYOR BELT

The equipment to sample from a conveyor belt is somewhat different than that used for sampling from a streamflow. The following is the equipment needed to secure a proper sample off a conveyor belt:

- **A template constructed to conform to the shape of the loaded belt. An adjustable spacer between the two ends of the template is helpful to allow for adjustment of the device to the amount of aggregate on the belt.**
- **A scoop or trowel to aid in removing the aggregate from the stopped belt.**
- **A brush or broom to aid in removing the fine particles of the increment from the belt surface.**
- **Sample containers, tags, etc.**
- **Safety equipment such as hard hat, gloves, glasses, etc.**

Sampling Procedure

Insert the template into the aggregate on the stopped conveyor belt being sure the template passes through the aggregate and rests on the surface of the belt as close as practicable. Do not sample the portions of material first discharged on the belt or material discharged as the bin empties. These areas are normally segregated and the sample will not be representative. Using the small scoop or hand, remove as much of the aggregate from the belt as possible. Brush the remaining fines into the sample container. A dustpan may be useful in some applications to collect the fines. Obtain at least three increments for each field sample being sure to collect the minimum mass needed to perform all applicable tests. When practicable, allow the belt to run awhile between each increment. This will aid in obtaining a sample more representative of the lot of material being tested.

Conveyor Belt Sampling

SAMPLING METHODOLOGY - STOCKPILES OR TRANSPORTATION UNITS

The equipment necessary to obtain a sample from a stockpile or transportation unit is listed below:

- **Sampling tube (approximately 1¼ in. (30 mm) minimum by 6 ft. (2 m) in length.**
- **Square-nosed shovel.**
- **Flat board**
- **Sample containers, tags, etc.**
- **Safety equipment, such as hard hat, gloves, glasses, etc.**
- **Front-end loader (if available)**

Sampling Procedure

Avoid sampling coarse or combined aggregate from stockpiles and transportation units whenever possible, especially when the sample taken is intended to determine characteristics dependent upon the grading of the sample. It is very difficult to ensure unbiased samples, due to the segregation which often occurs when material is stockpiled, with the coarser particles rolling to the outside base of the pile.

If circumstances dictate the need to obtain stockpile samples of coarse or combined aggregate, develop a sampling plan for the specific case under consideration. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained that is agreed upon by all parties concerned to be acceptable for the particular situation. This plan shall define the number of samples necessary to represent the lots and sublots of specific sizes. General principles for sampling from stockpiles apply to sampling from transportation units such as trucks, rail cars, and barges.

When available, have the power equipment create a small stockpile for sampling by drawing material from various levels and locations from the main pile. Several increments should then be sampled from this pile using the square-nosed shovel. Create as near a vertical face as practicable at several locations around the pile. A flat board shoved vertically into the pile just above the sampling point aids in preventing further segregation by holding the material above the location in place.

When power equipment is not available, the same method may be employed at various levels and locations around the main pile. A minimum of three increments must be obtained, one from the top third, one from the midpoint, and one from the bottom third of the pile.

If necessary to determine the degree of variability existing within the pile, separate samples should be drawn from separate areas of the pile.

Sampling from transportation units, power equipment, when available, should be used to expose the aggregate at various levels and random locations. A common procedure when power equipment is not available requires trenching at three or more locations across the unit in areas that visually appear to represent the characteristics of the load. The trench bottom should be approximately level, at least 0.3 m (1 ft.) in width and in depth below the surface. A minimum of three increments from approximately equally spaced points along each trench should be taken by pushing the shovel downward into the material.

Sampling of fine aggregates from stockpiles or transportation units should be accomplished with the sampling tube. The technician must be careful to avoid segregated areas such as around the base of the stockpile or unit to be sampled. Use a square-nosed shovel or other means to dig into the pile a little ways before insertion of the sampling tube. Insert the tube into the pile at several locations to extract a minimum of five increments of material to compile the field sample. This method should not be used for coarse or combined aggregates.

The technician may choose to sample the fine aggregate by creating a vertical face in the selected sample areas with a square-nosed shovel and then carefully slide the nose of the shovel in an upward motion from the base of the prepared sample area. The shovel should be held at an approximate ninety degree angle to the vertical face and inserted into the fine aggregate approximately 50 mm (2 in.). The aggregate should be in a damp condition to use this method.

When sampling a unit of fine aggregate, select at least three areas to obtain the individual increments, that when combined, will make up the field sample. The mass of the field sample must be large enough to provide enough material for each test to be performed on the aggregate.

Stockpile Sampling With a Probe

Stockpile Sampling With a Square-nosed Shovel

SAMPLING METHODOLOGY - ROADWAY (BASES AND SUBBASES)

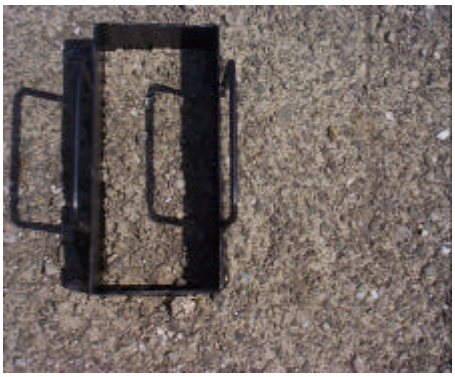
The equipment to sample aggregate from the roadway includes the following:

- **Square-nosed shovel.**
- **Square or rectangular template**
- **Sample containers, tags, etc.**
- **Safety equipment, such as hard hat, gloves, glasses, etc.**

Sampling Procedure

Selecting representative samples of aggregate in place creates a special challenge. A method of random sampling, such as found in Practice D 3665, must be used to help in obtaining unbiased samples.

Obtain at least three increments from the unit being sampled, and combine to form a field sample with a mass that meets or exceeds the minimum amount required for the type of material being sampled. Increments taken from the roadway must be to the full depth of the material. Care must be used to avoid contaminating the sample with underlying material. A square or rectangular template placed over the area to be sampled is a definite aid in securing approximately equal amounts of material in each increment. A square-nosed shovel may also be used to aid in defining the sample area.



Template Placed in Subbase

NOTE
Always remember when sampling in a construction zone to be aware of the activities around you.

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

ASTM D 3665

Developed by
FHWA Multi-Regional Aggregate Training and Certification Group
1999

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NOTE

ASTM D 3665, “Practice for Random Sampling of Construction Materials,” is a prerequisite for soils, aggregates, and hot mix training and certification materials presented in this package.

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

This practice covers the determination of random locations or times at which samples of construction materials are to be taken.

INTRODUCTION

Highway construction materials are typically accepted or rejected based on the test results of small representative samples. Consequently, acceptance or rejection of materials is highly dependent on how well a small sample that is tested represents a larger quantity of material. If the sample is not truly representative of the larger quantity, acceptable material could be rejected, or substandard material could be accepted. Correct sampling methods are critical to the validity of the sample test results. Sampling performed incorrectly will lead to test results that do not reflect the true characteristics of the material or product being tested.

A random sample is any sample which has an equal chance as any other sample of being selected from a large quantity. In other words, there is an equal chance for all locations and all fractions of a large quantity of material to be sampled. Random unbiased samples must be obtained in a way that the true nature of the material is represented. Samples should not be obtained on a predetermined basis or based on the quality of the material in a certain area. If sampling is not performed on a random basis, the quality of the sample can be artificially modified and the sample will no longer be representative of the larger quantity.

When a sample is not representative or random, it is said to be biased. Examples of biased sampling that should not be used include sampling a roadway at a given interval, such as every 1500 feet; sampling asphaltic concrete production at a given frequency, such as every 500 tons, or taking samples at a given time frequency, such as every hour on the hour. Random sampling eliminates bias due to improper sampling in the determination of materials characteristics.

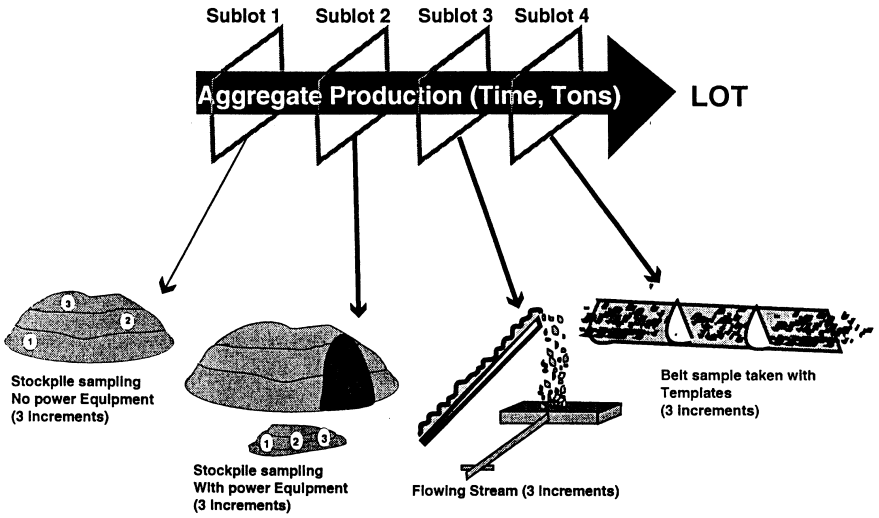


Figure 1. Example of random sampling techniques.

The actions required to obtain a good sample, such as how to take the sample, where to take it, what tools to use and the size of sample are covered in the appropriate materials control program and guidelines specified by the Agency for use on the project. Reference should be made to these instructions on sampling requirements.

Agency specifications identify lot sizes, locations, and frequencies for sampling and testing. A lot is defined as a given quantity of material that is to be sampled. The lot is a predetermined unit which may represent a day's production, a specified quantity of material, a specified number of truckloads or an interval of time. Agencies will specify the lot size of a material and often a sampling frequency. Although these frequencies may appear to be a violation of random sampling, they are given as a minimum amount of sampling, not as a specific frequency.

Lots are often divided into equal sublots. The number of equal sublots used to represent the lot will be determined by the agency and specifications, but in most cases four or more sublots compose a full lot.

Instructor's Note: Give an example of your Agency's materials control program, including lot sizes, sampling locations, and sampling frequencies.

Multiple sample portions might be required to be taken and combined to represent a single sample. For example, three sample portions are taken from an aggregate stockpile and combined to form a single sample. The sample will then be tested for determining the sublot or lot specification compliance. The use of random samples from sublots is referred to as stratified random sampling. Stratified random sampling assures that samples are taken from throughout the entire lot and are not concentrated in one area of the lot. See Figure 2.

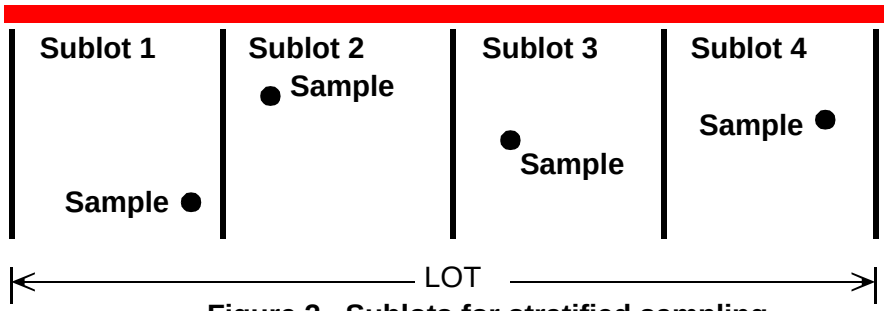


Figure 2. Sublots for stratified sampling.

Sample location or time determination should be fully independent of material production and construction activities. The established sample locations and times need to be confidential if they are identified before production or completion of the product occurs at the selected random locations and times. Under no circumstance should the material production or construction be modified because of knowing ahead of time of sample locations or times.

Quality control/quality assurance (QC/QA) specifications are developed based on statistical theory which is valid only when random sampling is performed. QC/QA specifications are statistically based on a normal distribution (bell curve) of material characteristics produced by a material production process or construction method. If samples are biased or not random, the test results will not fit the normal distribution and the QC/QA specification is no longer valid.

It is highly recommended that correlation sampling and testing is conducted between the QC and QA technicians and labs before or at the beginning of production to identify any discrepancies between the sampling and testing procedures and test equipment of the two labs and technicians. If this is not done, the differing test results due to test equipment deficiencies, different sampling techniques and/or different test method procedures may result in an apparent difference in material characteristics.

Random sampling is usually accomplished with the use of random number generators or tables of random numbers. Most calculators and computers contain a random number generator that merely requires the operator to hit a button. The automated random number generators use programmed tables of random numbers similar to the tables shown in Table 1. Random number tables can be of any length and are simply random arrangements of numbers within a given range of discrete numbers.

Do not attempt to create your own method of being random! There is no way you will be able to avoid personal bias or the creation of bias.

Instructor's Note: Examples of sampling that are not random and should be avoided-

- selecting a location because it looks good or bad
- choosing a time to sample that is convenient instead of random
- always sampling from the first truck each day to "assure the day is starting off right"
- throwing a dart at a table of random numbers in a manner that is selective
- throwing a rock and sampling where the rock lands.

SUMMARY

ASTM D 3665 - “Standard Practice for Random Sampling of Construction Materials,” is a method used by the industry for determining random locations or time intervals at which samples of construction materials are to be taken. The ASTM method uses tables of random numbers and describes the procedures for determining random times for belt sampling, random locations for windrow and stockpile sampling, random sampling of in-place paving materials, and random sampling of truck loads. This method does not describe actual sampling procedure, but rather, how to determine sampling times or locations.

METHOD

Picking Random Numbers:

If a calculator or computer random number generator is not used, the random number table adapted form ASTM D3665 and presented as Table 1 on the following pages can be used. The table contains all the numbers from 0.001 to 1.000, each number appearing only once.

1. Obtain two “pill boxes,” one box containing 100 “pills” numbered from 1 to 100 used for row determination in the table, and the other box containing 10 “pills” numbered from 0 to 9 used for column determination in the table.

2. Blindly, select a pill from the box containing 100 pills. For this exercise, say the pill with number 31 has been selected. Row 31 will then be used for the final random number selection from the table. **Always return the selected pill back into the box for further selections.**

3. Blindly, select a pill from the box containing 10 pills. Say the selected pill number is 5. Column 5 of the table will be used for the final random number selection**. Again, return the selected pill back into the box for further selections.**

4. Now locate the final random number in the table located at the intersection of row 31 and column 5. That number is 0.687, which is the random number which should be used for the determination of a sampling location or time frequency.

Keep in mind that for most situations, you’re going to need to pick several random numbers in order to obtain a final random number. This can take some time using the recommended procedure.

The final random numbers selected will represent feet from centerline offset and longitudinal direction from a station for roadway sampling or time for production sampling.

Instructor’s Note: The above method is easier than that presented in Section 5 of ASTM D3665 for the use of a random number table. If “pills” are not used, the method presented in Section 5 should be clearly explained.

Examples of Random Sampling Procedures using Random Numbers:

Sampling from a Belt or Flowing Stream of Aggregate: Determine an amount of produced material that is to be considered a lot quantity. Agencies will specify a time, such as a days production or a half-day production. Sometimes a volume, such as 764.6 cubic meters or 1000 cubic yards will be specified. AASHTO T2 - Sampling Aggregates, stipulates that when time is used to determine lot size, random numbers will be used directly to determine sampling time in minutes.

Example:

The lot size is a ten hour day (600 minutes) and the random numbers .324, .612, and .032 are chosen to represent three sublots. The decimal point is dropped and the times for sampling are then designated as 32 minutes, 324 minutes, and 612 minutes. Since 612 minutes is beyond the lot size of 600 minutes, .612 is discarded and another random number is chosen in its place. AASHTO allows the actual time to be rounded off to the nearest 5 minutes.

Example:

It is desired to take a random sample of aggregate for every 1000 tons of aggregate produced. The design requires 4123 tons of aggregate, therefore, 4 samples are required.

The random numbers selected from the table are: .87, .22, .38, .74.
Multiplying 4123 by each of these numbers gives the number of tons of production at which sampling should occur:

.22 x 4123 = 907 tons
.38 x 4123 = 1567 tons
.74 x 4123 = 3051 tons
.87 x 4123 = 3587 tons.

Sampling from Haul Units: Determine the number of units that comprise a lot. Multiply selected random numbers by the number of hauled units to determine sampling locations. In most cases, the number of hauled units of material will be anticipated at the beginning of the lot's production. Some agencies determine lot size based on tonnage shipped to projects, in which case the random numbers are multiplied by the total anticipated tonnage to determine sampling locations.

Sampling from a Roadway: Determine the length and width of a lot. Determine the number of samples required to represent the lot and pick random numbers for length and width. Determine sample locations by multiplying the lot length by a random number and the lot width by a random number. The length is typically measured from the beginning of the lot and the width is typically measured from the centerline or edge of structure.

Example:

Four samples are required for a 12 feet wide pavement with a lot size determined to be 4000 linear feet. The lot begins at Station 100+00. Use the random number table in Table 1 to determine the sample locations.

From the given information:

lot begins at station 100+00
lot ends at station 140+00
length of lot = 4,000 feet

Determine the sample locations:

Using the random number table, obtain two sets of 4 random numbers each.
Set 1 will be used to determine stationing (X) of the samples by multiplying the random numbers by 4,000 feet.
Set 2 will be used to determine the sampling distance from the right edge of pavement (Y) by multiplying the random numbers by 12 feet.

Random numbers chosen from table are:

Set 1: .13 .69 .59 .88
Set 2: .73 .82 .46 .33

Sample coordinate locations determination:

Sample #1:
X = .13 x 4000 = 520 feet
Y = .73 x 12 = 8.7 feet

Sample #2:
X = .69 x 4000 = 2760 feet
Y = .82 x 12 = 9.8 feet

Sample #3:
X = .59 x 4000 = 2360 feet
Y = .46 x 12 = 5.5 feet

Sample #4:
X = .88 x 4000 = 3520 feet
Y = .33 x 12 = 4.0 feet

Sample locations:

Sample #1:
Station 100+00 + 520 feet = Station 105+20 @ 8.7 feet from right edge of pavement

Sample #2:
Station 100+00 + 2760 feet = Station 127+60 @ 9.8 feet from right edge of pavement

Sample #3:
Station 100+00 + 2360 feet = Station 123+60 @ 5.5 feet from right edge of pavement

Sample #4:
Station 100+00 + 3520 feet = Station 135+20 @ 4.0 feet from right edge of pavement

Sampling of a Stockpile: ASTM does not recommend a method for using random numbers in determining the locations in stockpiles to sample. However, some agencies use random procedures for determining sampling increment locations from a stockpile. Keep in mind that stockpiles are prone to segregation and that a sample obtained randomly from a stockpile may not represent that material if it is not obtained in accordance with AASHTO T2-Sampling Aggregates.

Table 1.

ASTM D3665

RANDOM NUMBER TABLE, ADAPTED FROM ASTM D3665

	0	1	2	3	4	5	6	7	8	9
1	0.272	0.519	0.098	0.459	1.000	0.554	0.250	0.246	0.736	0.432
2	0.994	0.978	0.978	0.693	0.690	0.028	0.831	0.319	0.073	0.268
3	0.039	0.449	0.737	0.501	0.960	0.254	0.239	0.474	0.031	0.720
4	0.144	0.695	0.339	0.621	0.128	0.032	0.413	0.617	0.764	0.257
5	0.312	0.138	0.670	0.894	0.682	0.061	0.832	0.765	0.226	0.745
6	0.871	0.838	0.595	0.576	0.096	0.581	0.245	0.786	0.412	0.867
7	0.783	0.874	0.795	0.430	0.265	0.059	0.260	0.563	0.632	0.394
8	0.358	0.424	0.684	0.074	0.109	0.345	0.618	0.176	0.352	0.748
9	0.494	0.839	0.337	0.325	0.699	0.083	0.043	0.809	0.981	0.499
10	0.642	0.514	0.297	0.869	0.744	0.824	0.524	0.656	0.608	0.408
11	0.485	0.240	0.292	0.335	0.088	0.589	0.127	0.396	0.401	0.407
12	0.728	0.819	0.557	0.050	0.152	0.816	0.404	0.079	0.703	0.493
13	0.029	0.262	0.558	0.159	0.767	0.175	0.979	0.521	0.781	0.843
14	0.918	0.348	0.311	0.232	0.797	0.921	0.995	0.225	0.397	0.356
15	0.641	0.013	0.780	0.478	0.529	0.520	0.093	0.426	0.323	0.504
16	0.208	0.468	0.045	0.798	0.065	0.315	0.318	0.742	0.597	0.080
17	0.346	0.429	0.537	0.469	0.697	0.124	0.541	0.525	0.281	0.962
18	0.900	0.206	0.539	0.308	0.480	0.293	0.448	0.010	0.836	0.233
19	0.228	0.369	0.513	0.762	0.952	0.856	0.574	0.158	0.689	0.579
20	0.746	0.170	0.974	0.306	0.145	0.139	0.417	0.195	0.338	0.901
21	0.363	0.103	0.931	0.389	0.199	0.488	0.915	0.067	0.878	0.640
22	0.663	0.942	0.278	0.785	0.638	0.002	0.989	0.462	0.927	0.186
23	0.545	0.185	0.054	0.198	0.717	0.247	0.913	0.975	0.555	0.559
24	0.360	0.349	0.569	0.910	0.420	0.492	0.947	0.115	0.884	0.452
25	0.789	0.815	0.464	0.484	0.020	0.007	0.547	0.941	0.365	0.261

	0	1	2	3	4	5	6	7	8	9
26	0.279	0.609	0.086	0.852	0.890	0.108	0.076	0.089	0.662	0.607
27	0.680	0.235	0.706	0.827	0.572	0.769	0.310	0.036	0.329	0.477
28	0.078	0.444	0.178	0.651	0.423	0.672	0.517	0.660	0.657	0.972
29	0.676	0.830	0.531	0.888	0.305	0.421	0.307	0.502	0.112	0.808
30	0.861	0.899	0.643	0.771	0.037	0.241	0.582	0.578	0.634	0.077
31	0.111	0.364	0.970	0.669	0.548	0.687	0.639	0.510	0.105	0.549
32	0.289	0.857	0.948	0.980	0.132	0.094	0.298	0.870	0.309	0.441
33	0.961	0.893	0.392	0.377	0.864	0.472	0.009	0.946	0.766	0.287
34	0.637	0.986	0.753	0.566	0.213	0.807	0.017	0.460	0.515	0.630
35	0.834	0.121	0.255	0.453	0.376	0.583	0.422	0.371	0.399	0.366
36	0.284	0.490	0.402	0.151	0.044	0.436	0.747	0.694	0.136	0.585
37	0.038	0.814	0.594	0.911	0.324	0.322	0.895	0.411	0.160	0.367
38	0.351	0.283	0.027	0.220	0.685	0.527	0.943	0.556	0.853	0.612
39	0.143	0.384	0.645	0.479	0.489	0.052	0.187	0.990	0.912	0.750
40	0.512	0.056	0.018	0.122	0.303	0.803	0.553	0.729	0.205	0.925
41	0.296	0.705	0.156	0.616	0.534	0.168	0.564	0.866	0.739	0.850
42	0.451	0.536	0.768	0.518	0.481	0.880	0.835	0.734	0.427	0.847
43	0.837	0.405	0.591	0.370	0.104	0.848	0.004	0.414	0.354	0.707
44	0.724	0.153	0.841	0.829	0.470	0.391	0.388	0.163	0.817	0.790
45	0.665	0.825	0.671	0.623	0.770	0.400	0.068	0.440	0.019	0.944
46	0.573	0.716	0.266	0.456	0.434	0.467	0.603	0.169	0.721	0.779
47	0.332	0.702	0.300	0.570	0.945	0.968	0.649	0.097	0.118	0.242
48	0.755	0.951	0.937	0.550	0.879	0.162	0.791	0.810	0.625	0.674
49	0.439	0.491	0.855	0.446	0.773	0.542	0.416	0.350	0.957	0.419
50	0.700	0.877	0.442	0.286	0.526	0.071	0.154	0.988	0.333	0.626

	0	1	2	3	4	5	6	7	8	9
51	0.523	0.613	0.752	0.733	0.528	0.072	0.820	0.929	0.777	0.461
52	0.905	0.182	0.567	0.249	0.227	0.229	0.604	0.304	0.217	0.142
53	0.373	0.120	0.602	0.793	0.692	0.863	0.954	0.873	0.107	0.675
54	0.057	0.953	0.041	0.090	0.223	0.508	0.806	0.438	0.203	0.586
55	0.967	0.040	0.708	0.271	0.189	0.342	0.740	0.801	0.985	0.263
56	0.917	0.715	0.758	0.005	0.666	0.599	0.934	0.100	0.987	0.085
57	0.131	0.646	0.659	0.047	0.051	0.562	0.435	0.731	0.362	0.317
58	0.326	0.605	0.443	0.601	0.386	0.560	0.378	0.172	0.445	0.636
59	0.299	0.106	0.237	0.732	0.796	0.476	0.099	0.804	0.735	0.950
60	0.101	0.055	0.776	0.686	0.171	0.533	0.936	0.095	0.982	0.211
61	0.267	0.598	0.754	0.658	0.274	0.215	0.177	0.218	0.330	0.628
62	0.471	0.102	0.454	0.568	0.963	0.357	0.882	0.507	0.157	0.580
63	0.535	0.881	0.014	0.966	0.958	0.190	0.180	0.759	0.433	0.355
64	0.277	0.458	0.295	0.196	0.772	0.148	0.466	0.291	0.688	0.046
65	0.719	0.167	0.181	0.653	0.328	0.070	0.015	0.155	0.631	0.063
66	0.385	0.858	0.713	0.883	0.916	0.084	0.561	0.999	0.379	0.668
67	0.862	0.928	0.822	0.812	0.977	0.395	0.788	0.920	0.673	0.698
68	0.486	0.938	0.757	0.749	0.991	0.219	0.264	0.932	0.898	0.006
69	0.091	0.872	0.959	0.922	0.727	0.811	0.075	0.374	0.133	0.730
70	0.146	0.482	0.930	0.611	0.179	0.011	0.248	0.886	0.344	0.926
71	0.709	0.184	0.390	0.409	0.191	0.117	0.860	0.135	0.406	0.134
72	0.996	0.896	0.760	0.347	0.053	0.372	0.193	0.756	0.565	0.914
73	0.971	0.859	0.147	0.114	0.418	0.889	0.792	0.064	0.652	0.288
74	0.202	0.538	0.026	0.949	0.696	0.008	0.846	0.259	0.415	0.425
75	0.212	0.321	0.778	0.940	0.496	0.231	0.664	0.903	0.473	0.909

	0	1	2	3	4	5	6	7	8	9
76	0.207	0.799	0.487	0.022	0.813	0.891	0.500	0.368	0.725	0.437
77	0.818	0.503	0.906	0.224	0.904	0.892	0.455	0.343	0.924	0.197
78	0.701	0.984	0.174	0.141	0.704	0.908	0.048	0.828	0.997	0.058
79	0.035	0.380	0.001	0.381	0.251	0.497	0.214	0.794	0.552	0.588
80	0.221	0.200	0.587	0.353	0.584	0.270	0.885	0.110	0.956	0.711
81	0.647	0.403	0.530	0.738	0.280	0.457	0.650	0.276	0.661	0.973
82	0.667	0.722	0.327	0.723	0.410	0.635	0.012	0.907	0.316	0.677
83	0.644	0.590	0.021	0.369	0.042	0.062	0.387	0.183	0.964	0.544
84	0.302	0.123	0.116	0.282	0.851	0.256	0.648	0.845	0.782	0.993
85	0.633	0.933	0.331	0.546	0.842	0.016	0.236	0.164	0.923	0.976
86	0.060	0.681	0.683	0.775	0.624	0.955	0.126	0.655	0.919	0.113
87	0.165	0.532	0.431	0.341	0.092	0.244	0.222	0.336	0.034	0.216
88	0.875	0.691	0.383	0.382	0.596	0.301	0.275	0.188	0.868	0.805
89	0.726	0.902	0.252	0.130	0.238	0.398	0.763	0.463	0.615	0.140
90	0.273	0.393	0.285	0.161	0.619	0.865	0.551	0.030	0.571	0.258
91	0.253	0.821	0.600	0.023	0.606	0.849	0.610	0.577	0.082	0.774
92	0.340	0.654	0.173	0.495	0.498	0.992	0.192	0.506	0.751	0.129
93	0.194	0.290	0.592	0.983	0.509	0.998	0.522	0.627	0.741	0.540
94	0.166	0.450	0.210	0.204	0.840	0.826	0.833	0.516	0.965	0.375
95	0.712	0.314	0.033	0.823	0.629	0.939	0.887	0.066	0.743	0.081
96	0.622	0.800	0.710	0.575	0.678	0.465	0.802	0.969	0.150	0.784
97	0.313	0.294	0.897	0.718	0.614	0.876	0.025	0.049	0.620	0.125
98	0.137	0.087	0.003	0.483	0.201	0.209	0.320	0.935	0.447	0.787
99	0.243	0.679	0.844	0.069	0.024	0.543	0.714	0.234	0.505	0.428
100	0.361	0.359	0.230	0.761	0.334	0.149	0.511	0.475	0.854	0.119

GLOSSARY

bias - a systematic error which occurs in a method of sampling that affects the representativeness of the sample.

Lot - a predetermined quantity of material or production that is represented by a random sample.

Random sample - a sample taken from a quantity of material using a randomization process. A Random sample is any sample which has an equal chance as any other sample of being selected from a large quantity.

Stratified sampling - a method for ensuring that the full range of a construction process, Materials production, or lot of material is included in random sampling.

Sublots - equal subdivisions of a lot used in stratified sampling.

EXAMPLE EXAMINATION QUESTIONS

1. An asphaltic concrete sample location determined by random numbers is located in a small area of visible surface segregation. Since the area is small, the sample should be taken adjacent to the segregated area. True or False

2. Stratified random sampling means that a lot or large quantity of material is divided into sublots. True or False

3. The number .621 was selected from a random number table. This number should be rounded to .6 for determining a random location or time. True or False

4. The proper method for sampling a paving material is:
   A. sample at intervals of 1500 feet and take samples progressively from the shoulder to the longitudinal construction joint,
   B. obtain samples at evenly spaced time intervals to insure that there are no gaps in the lot that were not sampled,
   C. for each sample, select 2 random numbers and multiply the lot length and lot width by the random numbers to determine the sample location,
   D. select 1 random number and multiply the length of the lot and the width of the lot by that number to obtain a sample location.

5. When sampling from a belt, determine the lot size by tonnage and determine the number of samples needed. Random numbers selected represent the tonnage at which to take samples. True or False

6. A technician closed her eyes and picked the random number .913 in order to determine a column number. Using .913, she determined that column number 3 should be used to select the final random number. True or False

7. ASTM D3665 details the use of random numbers for sampling which of the following:
   A. roadway,
   B. stockpiles,
   C. belts or flowing aggregate stream,
   D. truckloads.

8. Random numbers picked are final, no matter what the situation, they must be used and not discarded or else the random method is not valid. True or False

9. When sampling from loaded trucks, determine which trucks to sample by picking the same number of random numbers from the table as number of required samples. Then, multiply the random numbers by the total number of trucks to determine which trucks to sample.

True or False

10. A loaded truck selected randomly for sampling can be sampled anywhere in the truck.

True or False

REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE

AASHTO T 248

Developed by
FHWA-Multi-Regional Aggregate Training & Certification Group
1999

TABLE OF CONTENT

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO D 3665, Practice for Random Sampling of Construction Materials

- AASHTO T 2, Sampling of Aggregates

GLOSSARY

Nominal Maximum Size - The largest sieve size listed in the applicable specification, upon which any material may be retained. (*Note: Occasionally the largest particles in a material as produced may be smaller than the nominal maximum size as defined and still be in specification compliance. Sample size and reduction method may be revised to reflect the material to be tested).*

Saturated Surface Dry (SSD) - An aggregate is considered to be in a saturated surface dry condition when there is no free moisture present but the aggregate is in a nonabsorbent state. In other words, the aggregate has all the moisture it can absorb and surface of the aggregate is dry.

Air Dry - When the aggregate appears to be dry but still has some absorbed moisture in its pore structure.

Fine Aggregate - Aggregate which has a nominal maximum size of the 4.75 mm (No. 4) sieve or smaller.

Coarse Aggregate - Aggregate which is predominately larger than the 4.75 mm (No. 4) sieve.

Combined Aggregate - Aggregate which has a blend of both coarse and fine particles.

REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE

Aggregates are the main ingredient in highway construction. They are used in all phases from base construction, pavement mix, granular shoulders, and granular surfacing, as well as, erosion control. In order to ensure the aggregate performs as intended for the specified use, a variety of tests must be performed on the aggregate. These samples must be representative of the aggregate selected for use and should be obtained by appropriate methods as described in AASHTO T 2.

The field samples of aggregate must generally be reduced to an appropriate size for testing to determine physical characteristics, such as, sieve analysis, soundness, hardness, etc. The methods described in this text are intended to minimize variations in the aggregate characteristics between the smaller test samples and the larger field samples.

Several methods of sample reduction will be described. The technician must be sure to use the appropriate technique dependent on such factors as aggregate size and moisture content.

The reduction methods include:

Method A - Mechanical Splitter

Method B - Quartering

Method C - Miniature Stockpile

In some circumstances, reducing the field sample prior to testing is not recommended. Substantial differences may unavoidably occur during sample reduction, i.e., in the case of an aggregate having relatively few large size particles in the sample. These few particles may be unequally distributed among the reduced size test samples. If the test sample is being examined for certain contaminants occurring as a few discreet particles in a small percentage, the reduced test sample may not be truly representative of the total aggregate as produced. In these cases, the entire original field sample should be tested.

Failure to carefully follow the procedures in these methods of sample reduction may result in providing a nonrepresentative sample for subsequent testing, resulting in inaccurate test results, and ultimately, failure of the aggregate to perform as intended.

SUMMARY OF SAMPLE REDUCTION

Aggregate and other materials sampled in the field need to be reduced to appropriate sizes for testing. It is, therefore, necessary to reduce field samples while minimizing the chance of variability during handling. In some instances a few particles on a given sieve might effect a gradation significantly enough to alter an interpretation of the field sample and subsequently the entire lot's compliance with specifications.

The appropriate field sample reduction method is dependent chiefly on the nominal maximum size of the aggregate, the amount of free moisture in the sample, and the equipment available.

The glossary at the back of this section should be read thoroughly before proceeding with sample reduction

The following chart should be used in selecting the appropriate reduction method for the aggregate to be tested.

Mechanical Splitter	**Quartering**	**Miniature Stockpile**
Fine Aggregates - Air Dry	Fine Aggregates - Free Moisture on the Particle Surface	Fine Aggregate - Free Moisture on the Particle Surface
Coarse Aggregates	Coarse Aggregates	Not Appropriate for Coarse Aggregate
Combined Aggregates	Combines Aggregates with Free Moisture on the Particle Surface	Not Appropriate for Combined Aggregate

COMMON SAMPLE REDUCTION ERRORS

- Failure to obtain a field sample using the methods and guidelines given in AASHTO T 2.
- Failure to select proper method for sample reduction based on aggregate moisture content.
- Failure to uniformly distribute the field sample from edge to edge while placing it in the hopper or pan prior to pouring it through the chutes when using a mechanical splitter.
- Failure to, when using a mechanical splitter, control the rate at which the materials are poured through the chutes such that the material is free flowing into the receptacle pans below. This includes using a hopper or straight-edged pan that, per AASHTO T 248, has a width equal to or slightly less than the overall width of the assembly of chutes.
- Failure to use mechanical splitters which meet the applicable requirements for number of chute openings and chute width.
- When using the quartering method or miniature stockpile method, failure to mix the sample thoroughly by turning the entire sample over three times.
- When using the quartering method, failure to brush the cleared spaces clean of fines after removing the two diagonally opposite quarters from the flattened field sample.
- When using the miniature stockpile method, failure to obtain the five (minimum) increments of material from random locations in the miniature stockpile. Do not take all five samples from the same location.

SAMPLE REDUCTION - METHOD A (MECHANICAL SPLITTER)

Before beginning any procedure, you must first assemble all the equipment needed to perform the test.

Apparatus

The mechanical sample splitter shall have an even number of equal width chutes, not less than eight for coarse or combined aggregate, or twelve for fine aggregate. The chutes shall discharge alternately to each side of the splitter. For coarse and combined aggregates the minimum width of the individual chutes shall be approximately fifty percent larger than the largest size particle in the sample to be reduced. For dry fine aggregate in which the entire sample will pass the 9.5 mm (d in.) sieve, the minimum width of the chutes shall be at least fifty percent larger than the largest particles in the sample with a maximum width of 20 mm (¾ in.).

The splitter shall be equipped with at least two receptacles(catch pans) to hold the two halves of the sample during splitting. It shall also be equipped with a hopper or straight-edge pan with a width equal to or slightly less than the overall width of the assembly of chutes, by which the sample may be fed at a controlled rate into the chutes.

The splitter and accessories shall be designed to allow the sample to flow smoothly without restriction or loss of material.

Mechanical splitters are commonly available in sizes adequate for aggregate having the largest particle size not over 37.5 mm (1½ in.).

Sample Preparation

When choosing the mechanical splitter to reduce a fine aggregate sample, the aggregate should be in an air dry condition. The entire sample may be dried to at least a saturated surface dry condition using temperatures that do not exceed those specified for any of the tests intended to be performed on the material.

If the damp, fine aggregate sample is too large to efficiently dry in this manner, a preliminary split may be performed using a mechanical splitter with chute openings no smaller than 38 mm (1½in.). Reduce the sample to not less than 5000 g and dry this sample. Reduce the dried sample using a mechanical splitter with individual chute openings not to exceed 20 mm (¾ in.) to the required test sample size(s).

When reducing a coarse aggregate by mechanical splitting, the sample may be reduced in a damp condition taking care that any fine particles adhering to the chutes are brushed into the catch pans. Samples containing excess water should be allowed to drain before reduction is attempted.

Combined aggregates may also be reduced in a damp condition, as long as the aggregate flows freely through the chute openings without plugging and any small particles adhering to the chutes are brushed into the catch pans.

When practicable, allow all samples to attain an air dry condition before using a mechanical splitter.

Note: *If the field sample was originally collected in two or more increments (separate sacks containing material from different parts of the same stockpile), then the separate increments must be thoroughly mixed together to form one homogenous field sample. Mixing can be done using an adequate sample splitter or by mixing the sample with a shovel as detailed later in the section describing the quartering method procedure.*

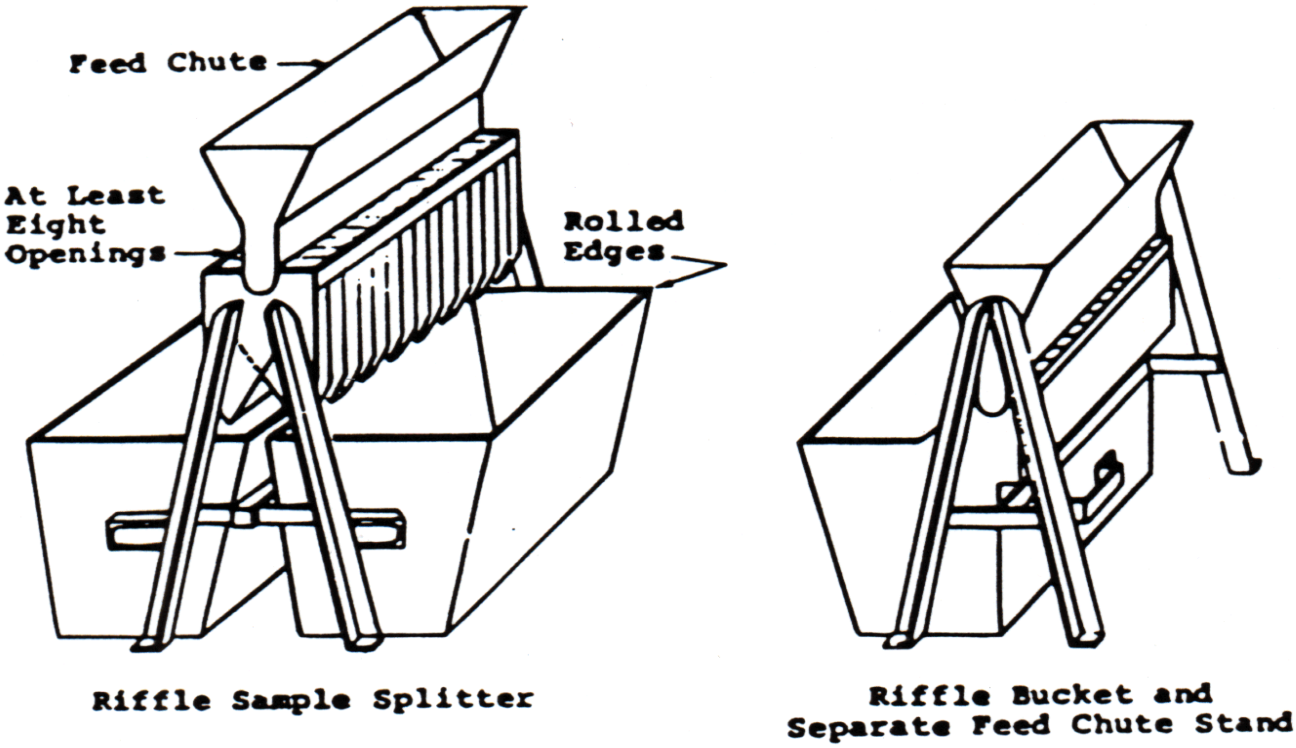
Reduction Procedure

Place the original sample, or portion thereof, in the hopper or pan and uniformly distribute it from edge to edge being sure the sample appears homogenous (well-blended). Carefully introduce the sample into the chutes in a manner to allow the aggregate to flow freely through the openings and into the catch pans. Continue this procedure until the entire large sample has been halved, being careful that catch pans do not overflow.

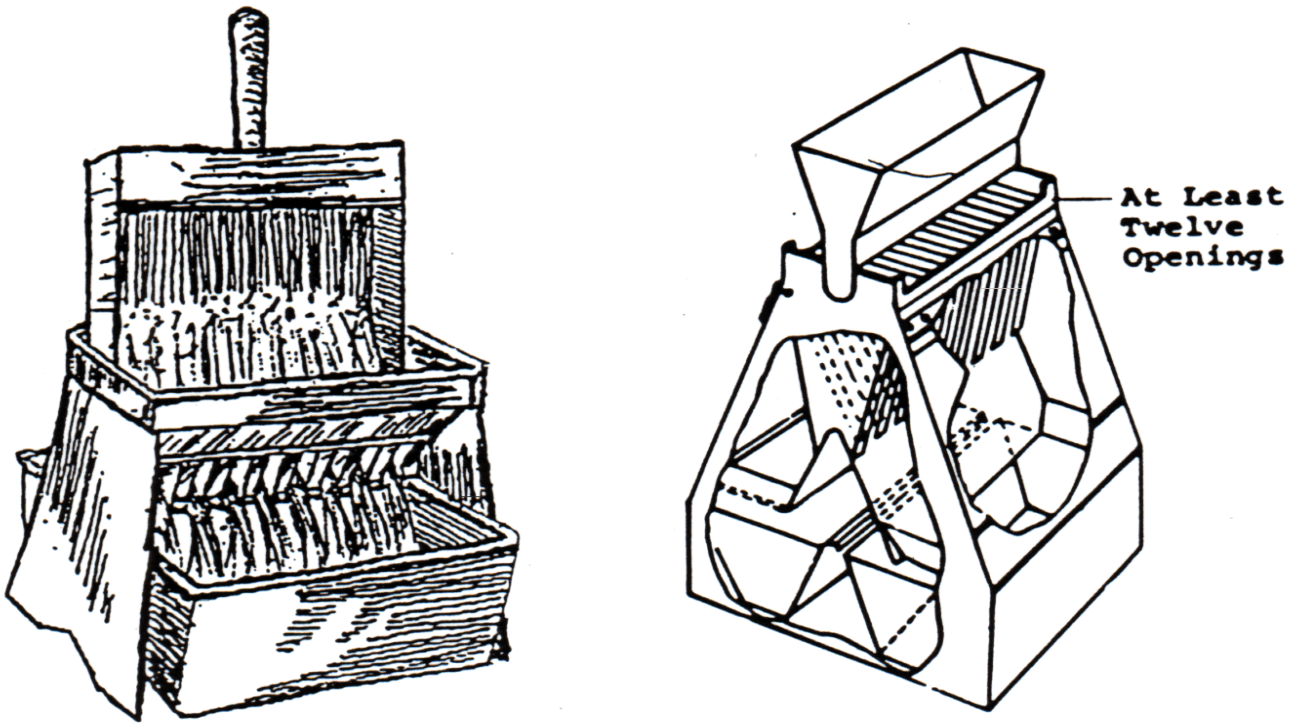
Remove the catch pans and set aside. Continue splitting the other half into quarters. Follow this procedure, being sure to split entire increments, until the desired test sample size is obtained. Retain the unused material until all desired tests are performed in case a retest is needed.

The mechanical splitter method is the preferred method of sample reduction and should be used when practicable. Mechanical splitters are commonly available in sizes adequate for aggregates with particle sizes up to 37.5 mm (1½ in.).

Note: *Sometimes a significant amount of fines may be lost in the splitting process if the sample is extremely dry and the action of pouring the sample through the splitter chutes creates a large dust cloud, suspending the fines in the air above the splitter. If this is a serious concern, then add a small amount of water to the original sample and mix thoroughly before splitting the sample. The extra moisture will prevent many of the fines from becoming suspended in the air and drifting off. Remember to not add so much water that the moisture content ends up being at or greater than the SSD condition, in which case the mechanical splitting method would no longer be valid. In any case, be sure to perform the splitting procedure in a well-ventilated area while wearing a suitable dust mask (one which is designed to protect against silica dust) or injury to the lungs, over time, may result.*



(a) Large Riffle Samplers for Coarse Aggregate.



NOTE—May be constructed as either closed or open type. Closed type is preferred. (*b*) Small Riffle Sampler for Fine Aggregate.

FIGURE 1 Sample Splitters

MECHANICAL SAMPLE SPLITTER

Mechanical Splitter

Sample in Splitter

Sample Being Split

SAMPLE REDUCTION - METHOD B (QUARTERING)

Apparatus

The following are the apparatus needed to perform Method B.

- Straight-edged scoop.
- Flat-edged shovel or trowel.
- Broom or brush.
- Alternate method only - canvas blanket measuring approximately 2 m by 2.5 m (6 ft. X 8 ft.).

Sample Preparation

Fine aggregate must be in a moist condition to use Method B - quartering, to reduce the sample. The material should be damp enough to allow it to stand in an almost vertical face.

Coarse aggregate may be either damp or dry when using Method B. (*Method A is the preferred sample reduction method for coarse aggregates).*

Combined aggregates must be in a moist condition to reduce the sample by Method B, again able to stand in an almost vertical face.

Reduction Procedure

Place the original sample on a hard, clean, level surface. Mix the material thoroughly by turning the entire sample over with the shovel three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with the shovel so that each quarter section of the resulting pile will contain the material originally in it. The pile diameter should be approximately four to eight times the thickness.

Divide the flattened pile into four equal quarters with the shovel or trowel. Remove two diagonally opposite quarters, including all fine material. Brush the cleared spaces clean. Successively mix and quarter the remaining material in the same fashion as the original sample. Continue this process until the desired quantity is obtained.

Save the unused portion of the original field sample until all testing is completed in case a retest is needed.

METHOD B - ALTERNATIVE

As an alternative to Method B, when the floor surface is uneven, the field sample may be placed on a canvas blanket and mixed with a shovel, or by alternatively lifting each corner of the blanket and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten and divide the pile as described in Method B, or if the surface beneath the blanket is too uneven, insert a stick or pipe dividing the pile into two equal parts. Remove the stick leaving a fold in the canvas between the sample halves. Slide the stick under the canvas blanket again at a right angle to the first division and dissecting the two halves of the sample through their centers. Lift the stick evenly from both ends dividing the sample into equal quarters. Remove two diagonal parts including the fine material and clean the area. Successively mix and quarter the remaining material until the desired sample size is obtained.

Note: *The quartering method is fairly time intensive and thus is generally used in situations where an adequate mechanical splitter is unavailable. Diligence and care is required to ensure that the samples obtained by quartering remain representative of the entire field sample.*

METHOD B

Mix by Forming New Cone

Flatten Cone

Divide Sample Into Quarters

Method B (alternative)

Stick Placed Under Flattened Sample

Sample Divided in Half

Sample Divided Into Quarters

SAMPLE REDUCTION - METHOD C (MINIATURE STOCKPILE)

APPARATUS

The equipment needed to reduce an aggregate sample using Method C include the following items.

- Straight-edged scoop.
- Shovel or trowel (for mixing the aggregate).
- Small sampling thief, small scoop, or spoon.

Sample Preparation

The miniature stockpile method must only be used when reducing a sample of fine aggregate. The sample must be in a moist condition before performing this method.

Reduction Procedure

This method is for damp, fine aggregate only.

Place the field sample on a hard, clean, level surface where there will be no loss of material or contamination. Mix the sample by turning the entire sample over three times with a shovel. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing on the apex of the conical pile with the shovel.

Obtain a sample for each test to be performed by selecting at least five increments of material at random locations from the miniature stockpile using a sample thief, small scoop, or spoon.

Miniature Stockpile

Taking One Of At Least Five

TOTAL MOISTURE CONTENT OF AGGREGATE BY DRYING

AASHTO T255

Developed by:

Federal Highway Administration Multi-Regional
Aggregate Training and Certification Group

July, 1999

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NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T2, Sampling
- ASTM D3665, Practice for Random Sampling of Construction Materials

TOTAL MOISTURE CONTENT OF AGGREGATE BY DRYING

Scope

Aggregates are the main ingredient in highway construction. They are used in all phases from base construction, pavement mix, granular shoulders, and granular surfacing, as well as, erosion control. In order to ensure the aggregate performs as intended for the specific use, a variety of tests must be performed on the aggregate. One such test is the moisture content of an aggregate. The moisture content in aggregate needs to be determined to identify aggregate absorption, a base to determine maximum allowable water concern for portland cement concrete, moisture restrictions for hot mix asphalt, and determination of density.

Basically, a known amount of material is taken, heated to drive off the moisture and the percentage moisture determined. Several methods of heating can be used, including:

- Hot plate
- Oven
- Microwave oven

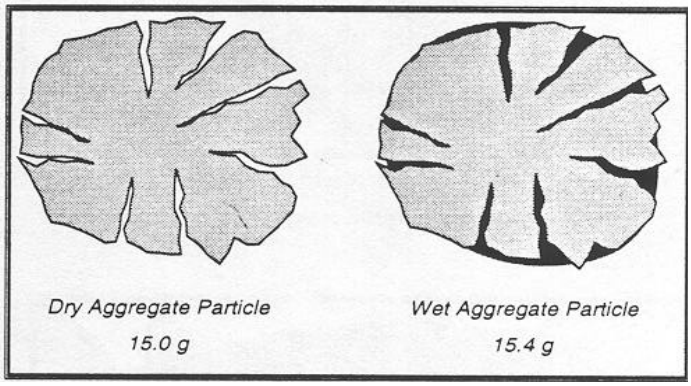


Fig. 1 Moisture Content Diagram

Apparatus

Balance, general purpose, meeting requirements of AASHTO M231

Source of heat for aggregate: A ventilated oven capable of maintaining a temperature of 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.), or a hot plate (Figure 2), electric heat lamps, microwave oven.

Sample container for aggregate: Should be suitable for method selected, not affected by heat.

Stirrer to mix sample while drying to assist in water evaporation.

Fig. 2 Hot Plate Use in Field

Procedure

1. Select the proper sample size based on the following table (Table 1).

Table 1

Aggregate Moisture Content Sample Sizes	
Nominal Maximum Size, mm (in.)	Minimum Sample Mass
4.75 (#4)	0.5 kg/ 1.1 lbs.
9.5 (3/8)	1.5 kg/ 3.3 lbs.
12.5 (1/2)	2 kg/ 4.4 lbs.
19.0 (3/4)	3 kg/ 6.6 lbs.
25.0 (1)	4 kg/ 8.8 lbs.
37.5 (1 1/2)	6 kg/ 13.2 lbs.
50.0 (2)	8 kg/ 17.6 lbs.

2. Obtain the sample according to AASHTO T2, and protect it from moisture loss during transport to the testing site. An air-tight container or plastic bag is best for this purpose.

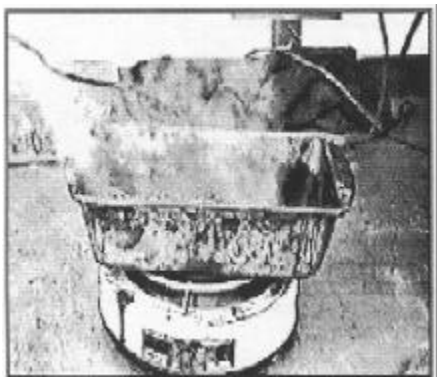
3. Weigh the sample to the nearest 0.1 5 (Figure 3), and record this mass as the original wet mass, W, of the sample.

Fig. 3 -Weigh to nearest 0.1 g

4. For aggregates, dry the sample in a suitable container on a selected source of heat (Figure 4) until the sample shows less than 0.1 % change in mass over subsequent weighing. Record the mass of the dried aggregate (after it has cooled sufficiently so as not to damage the scale) to the nearest 0.1 % as the dry mass, D.

NOTE: In the event that you encounter material with a nominal size aggregate over 37.5 mm (1 ½"), be aware that larger aggregate particles require longer drying time.

Fig. 4 - Dry in a suitable manner depending on type of aggregate



NOTE: Avoid heating the aggregate sample so fast that steam causes the aggregate to break or spatter (Figure 5.)

Fig. 5 - Heating the aggregate too fast, causing heavy steam generation

Heat Sources for Aggregate Drying

There are several alternatives to chose from when drying aggregates.

Hot Plate: an excellent choice when you're in a hurry, just be careful to avoid excessive localized overheating and fracturing of aggregates. When you use a hot plate, be sure to stir the sample repeatedly while observing the state of the aggregate. Some types of aggregate will not tolerate the high localized heat and may fracture despite the best of care. In this case, use an oven.

Note: If fracturing of the aggregate occurs, take another sample and retest.

Oven: The most common is probably an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.). An oven is a good choice when time is not of the essence. Samples dried in the oven, depending on the type of container you use and the moisture content of the sample, can take anywhere from one to several hours to dry to a constant mass. The benefit of using an oven is that it's very unlikely that sensitive aggregate will overheat and fracture. If you are working with sensitive aggregates, then, an oven is probably you best choice. If you are working with a material that also contains soils or highly absorbent clay, they may be affected by excessive moisture within the oven as other items are drying. Check the oven's evaporation rate in accordance with AASHTO T104 to optimize drying time.

Microwave: this is quicker solution than a hot plate, except that microwave drying will often fracture and pop the aggregate particles. Some experimentation will be necessary to ensure the best settings for your material, to avoid this situation.

SAFETY CAUTION - The microwave should NOT be used where there is metal or metal oxides present in the aggregate.

Calculation

The calculation for moisture content (P) is as follows:

Multiply the difference of the original wet mass (W) and dry mass (D) X 100 and divide by the dry mass (D). Round the result to the nearest 0.1.

$$P = 100 \frac{(W - D)}{D}$$

where:

P = moisture content of sample, %
W = original wet mass of sample, gms
D = dry mass of sample, gms

Example:

W = 546.2 gms, D = 541.2 gms

$$P = 100 \frac{(546.2 - 541.2)}{541.2}$$

$$P = \frac{500}{541.2}$$

P = 0.92 % , record as 0.9 %

COMMON ERRORS

- Overheating
- Insufficient sample size
- Loss of material when stirring
- Pre-drying of the sample
- Use of a volatile with the hot plate

QUIZ - TRUE OR FALSE

1. Moisture content of aggregates can only be run on particles with sizes greater than 37.5 mm (1 ½").

2. When drying aggregates for moisture content, the samples should always be placed in an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.).

3. Extra care should be taken when using a microwave to dry aggregates to ensure that the particles are not cracking and popping.

4. When transporting the moisture content sample to the testing facility, make sure it is in an airtight, sealed container to prevent the loss of moisture from the sample.

5. For a sample whose dry mass was 234.0 gms and original mass was 264.3 gms, the moisture content was calculated to be 12.9 %.

6. For an aggregate sample with a nominal size of 19.0 mm (3/4"), the minimum size of the moisture content sample is required to be 6.6 kg (3 lbs.).

7. When using a hot plate to dry aggregate, be sure to stir the sample frequently to prevent localized overheating and aggregate fracturing.

8. Samples with larger aggregate particles usually tend to dry more quickly than samples with smaller aggregate particles.

9. It is advisable to remove dried samples from an oven prior to placing wet samples in the same oven.

10. Samples may be assumed to have dried to a constant mass when they have been in an oven for a length of time that has been previously demonstrated to achieve constant mass for samples of a similar nature with similar oven loading conditions.

Moisture content Calculations

Wet Mass, gms	Dry Mass, gms	Loss, gms	Moisture Content, %
523.2	519.8		
1564.2	1538.1		
555.2	525.2		
681.5	681.0		
339.7	300.1		

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

AASHTO T 27

Developed by
FHWA Multi-Regional Aggregate Training and Certification Group

July, 1999

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SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package

- AASHTO T2, Sampling
- ASTM D3665, Practice for Random Sampling of Construction Materials
- AASHTO T248, Reducing Samples of Aggregate to Testing Size

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

Scope

Aggregates are the main ingredient in highway construction. They are used in all phases from base construction, pavement mixes, granular shoulders, and granular surfacing, as well as erosion control. In order to ensure the aggregate performs as intended for the specific use, a variety of tests must be performed on the aggregate. One such test is the sieve analysis of fine and coarse aggregates. The sieve analysis, commonly known as the “gradation test” is a basic essential test for all soils and aggregate technicians. The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. The gradation data can be used to calculate relationships between various aggregate or aggregate and soils blends, to check compliance with such blends, and to predict trends during production by plotting gradation curves graphically, to name just a few uses. Used in conjunction with other tests, the sieve analysis is a powerful quality control and quality acceptance tool.

NOTE: Accurate determination of material passing the 0.075 mm (#200) sieve cannot be made with this test alone. It is recommended under this test to use this test in conjunction with AASHTO T11 in order to determine the amount of material finer than the 0.075 mm (#200) sieve.

Summary of Test

A known amount (mass) of material, the amount being determined by the largest size of aggregate, is placed upon the top of a group of nested sieves (the top sieve has the largest screen openings and the screen opening sizes decrease with each sieve down to the bottom sieve which has the smallest opening size screen for the type of material specified) and shaken by mechanical means for a period of time. After shaking the material through the nested sieves, the material retained on each of the sieves is weighed used one of two methods.

The cumulative method is as follows:

Each sieve beginning at the top is place in a previously weighted pan (known as the tare weight), weighed, then the next sieve's contents are added to the pan and the total weighed. This is repeated until all sieves and the bottom pan have been added and weighed.

The second method is to weigh the contents of each sieve and the bottom pan individually. Do not discard material until entire test is completed. Either method is satisfactory to use and should result in the same answer. The amount retained and passing the sieve is then calculated.

Apparatus

Balance, general purpose class (AASHTO M231)

Sieves, mounted on suitable frames, designed not to leak. Sieves shall conform to AASHTO M92.

Mechanical sieve shaker if used, must provide a vertical or lateral and vertical "motion to the sieve, causing the particles thereon to bounce and turn so as to present different orientations to the sieving surface". Sieve shaker must provide sieving thoroughness within a reasonable time.

Oven, capable of maintaining 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.).

Sample Preparation

Samples should be obtained in the field and reduced to test size in compliance with the applicable test methods (AASHTO T2 and AASHTO T248). Samples should be dried to a constant mass in an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.), except where

control situations necessitate rapid test results on coarse aggregate. AASHTO T27 allows for coarse aggregate to be run in a moist condition so long as the nominal maximum size of the aggregate is greater than 12.5 mm (½"). Drying is also allowed on a hot plate so long as the particles do not fracture nor the aggregate change chemically under the heat. Use the following table (Table 1) to determine appropriate sample sizes based on the nominal maximum size of the aggregate in the sample to be tested.

Table 1

AASHTO Sample Sizes for Aggregate Gradation	
Nominal Maximum Size Agg. mm (in.)	Minimum Mass of Test Sample
9.5 (3/8")	1 kg (2 lb.)
12.5 (1/2")	2 kg (4 lb.)
19.0 (3/4")	5 kg (11 lb.)
25.0 (1")	10 kg (22 lb.)
37.5 (1 1/2")	15 kg (33 lb.)
50.0 (2")	20 kg (44 lb.)
63.0 (2 1/2")	35 kg (77 lb.)
75 (3")	60 kg (130 lb.)
90 (3 1/2")	100 kg (220 lb.)

NOTE:
Aggregate with at least 95% passing a 2.36 mm (#8) sieve.....100 g

Aggregate with at least 85% passing a 4.75 mm (#4) and more than 55 retained on a 2.36 mm (#8) 500g

For materials containing a mixture of fine and coarse aggregate, always use the mass from the coarse aggregate table.

NOTES ON SAMPLE SIZES: these sample sizes are standard for aggregate testing, but due to equipment restraints samples may need to be partitioned into several “sub-samples” that will comprise the final test. For example, a gradation test on a material with a nominal maximum size of 75 mm (3"), which requires 60 kg (130 lb.) sample size, would absolutely not fit into a large tray shaker in one increment.

Procedure

1. Weigh the sample to the nearest 0.1% by total mass of sample. This mass will be

used to check for any loss of material after the sample has been graded. Select suitable sieve sizes in accordance with agency specifications. Standard sieve sizes recognized by AASHTO may differ from region to region. Always consult local specifications in order to determine the proper sieve sizes.

Figure 1 - Large Tray Shaker

2. Nest the sieves in order of decreasing size from top to bottom and begin agitating and shaking the sample for a sufficient amount of time.

For coarse aggregate, the large tray shaker is most commonly used (Figure 1). This device provides a clamping mechanism which holds the sieve in place during agitation. "Shakers"of this make usually need to be run a minimum of 7 minutes to adequately grade the sample.

Figure 2 - Small Sieve Shaker

For fine aggregate, round 203.2 mm (8") sieves are commonly used (Figure 2). These sieves are self-nesting and supported in a shaking mechanism at the top and bottom by
a variety of clamping and/or holding mechanisms. "Small shakers" of this type usually require shaking times of 10 minutes to adequately grade the fine aggregate sample.

NOTE: Every effort should be made to avoid overloading the sieves. AASHTO defines overloading large sieves as mass retained in excess of 2.5 times the sieve opening in mm, as expressed in kg/m^2. For a 19.0 mm (3/4") sieve, this means in excess of 47.5 kg/m^2 (9.7 lb/ft^2) is considered an overloaded sieve. For fine aggregate, no mass shall be in excess of 6 kg/m^2. This amounts to 194 g on any small round 203 mm (8") sieve.

3. <u>For coarse aggregates</u>

After the material has been sieved, remove each tray and weigh each size and record each mass to the nearest 0.1% by total mass. Be sure to remove any aggregate trapped within the sieve openings by gently working from either or both sides with your hands until the aggregate is freed. Banging the sieve on the floor or hitting it with a

hammer will damage the sieve. The final total of the masses retained on each sieve should be within 0.3% of the original mass of the sample prior to grading. Particles larger than 75 mm (3") should be hand-sieved. When passing large stones through sieves, do not force the aggregate through the sieve openings.

4. For Fine Aggregate

Weigh the material retained on each sieve size to the nearest 0.1% by total mass. Ensure that all material entrapped within the openings of the sieve are cleaned out and included in the mass retained. This can be done using brushes to gently dislodge entrapped materials. The 203 mm (8") round sieves need to be handled with special care due to the delicate nature of their screen sizes. As a general rule, use coarse wire brushes to clean the 203 mm (8") sieves down through the 0.60 mm (#30) sieve (Figure 3). Any sieve with an opening size smaller then the 0.60 mm (#30) should be cleaned with a softer cloth hair brush (Figure 4). The final total of the masses retained on each sieve should be within 0.3% of the original mass of the sample prior to grading.

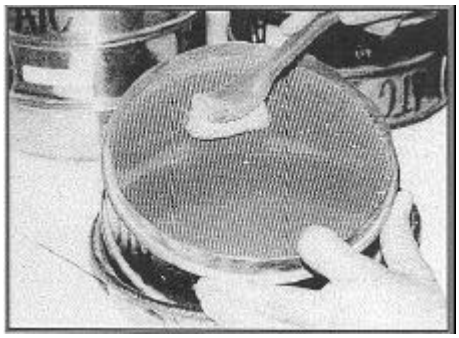

Figure 3 - Use Wire brush on Coarse Sieve

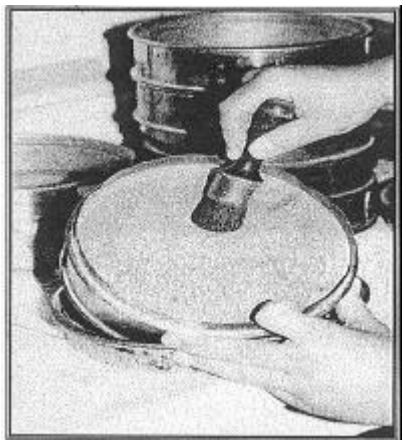

Figure 4 - Use Hair Brush on Fine Sieves

Periodically check sieves for signs of wear and tear and possible biasing of test results (Figure 5). In particular, inspect the sieve screens for holes or aberrations, or cracks along the outer rim (Figure 6). Sieves with bowed screens that are not taut need to be discarded or re-screened.

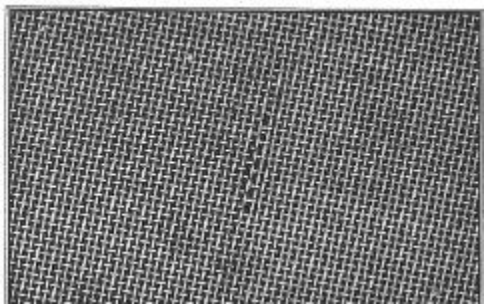

Figure 5 - Torn Sieve

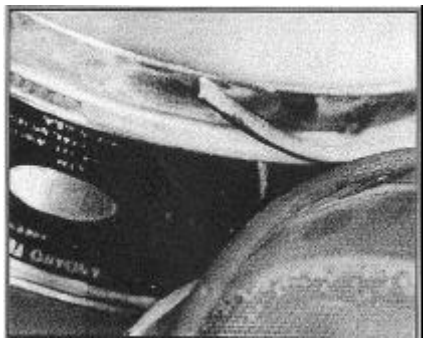

Figure 6 - Cracked Outer Seam

Checking Sieving Thoroughness

The technician should check the sieving thoroughness periodically (Figure 7). AASHTO requires each sieve to be tested for thoroughness in the following manner: “Hold the individual sieve, provided with a snug fitting cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at a rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes”. After this procedure, weigh the material that has passed through the sieve and into the pan. If the mass exceeds more than 0.5% of the total mass of the sample, then the sieving thoroughness for that sieve (and shaker) is inadequate, and it is possible that increased shaking times are required. For a 500 gram sample each sieve should lose no more than 2.5 grams on any sieve after the above prescribed procedure.

Figure 7 Checking Sieve Thoroughness

Calculation

Two methods are typically used to calculate a gradation in order to determine the percentage of material either retained or passing on each sieve; cumulative, or non-cumulative. Both are shown here to illustrate the calculation. Neither method is specified in AASHTO.

Cumulative Method

1. Tare the pan. Place the material retained on the top most sieve into the pan and record the mass. Place subsequent materials on sieves beneath each other into the pan and record the cumulative mass as you place materials into the pan. Do not tare the scale until the entire cumulative mass (down to the pan) has been recorded. The final mass on the scale is the total mass of the sample. In this example, material passing the 4.5 mm (#4)) sieve was graded with a combined total mass of 829.8 gms (Figure 9).

Sieve Size	Cumulative Mass	Cumulative % Retained	%Passing
4.75 mm (#4)	96.8		
2.00 mm (#10)	383.3		
0.850 mm (#20)	709.1		
0.600 mm (#30)	774.4		
0.425 mm (#40)	801.5		
0.180 mm (#80)	820.4		
0.075 mm (#200)	826.5		
Total	829.8		

Figure 9. Record the cumulative mass of materials retained on the sieves.

2. Cumulative % retained is calculated by dividing the cumulative mass retained on each sieve by the total mass of the sample and multiplying by 100 (Figure 10). In this example the 4.75 mm (#4) sieve had 96.8 gms retained. This mass divided by the total mass (829.8) and multiplied by 100 is 11.7 %. This process is repeated for the remainder of the sieves.

Sieve Size	Cumulative Mass	Cumulative % Retained	%Passing
4.75 mm (#4)	96.8	**11.7**	
2.00 mm (#10)	383.3		
0.850 mm (#20)	709.1		
0.600 mm (#30)	774.4		
0.425 mm (#40)	801.5		
0.180 mm (#80)	820.4		
0.075 mm (#200)	826.5		
Total	829.8		

Figure 10. 96.8 grams retained on the 4.75 m (#4) sieve, divided by the total mass (829.8 g) and multiplied by 100 is 11.7%.

3. Percentage passing is determined for each sieve by taking the cumulative percent retained on that sieve and subtracting 100 from it. In this example, 100 - 11.7 = 88.3 % passing the 4.75 mm (#4) sieve (Figure 11). This process is repeated for the remainder of the sieves.

Sieve Size	Cumulative Mass	Cumulative % Retained	%Passing
4.75 mm (#4)	96.8	11.7	**88.3**
2.00 mm (#10)	383.3	46.2	
0.850 mm (#20)	709.1	85.5	
0.600 mm (#30)	774.4	93.3	
0.425 mm (#40)	801.5	96.6	
0.180 mm (#80)	820.4	98.9	
0.075 mm (#200)	826.5	99.6	
Total	829.8	100.0	

Figure 11. 100–11.7 = 88.3 % Passing.

4. The advantage to the cumulative method (Figure 12) is that the technician does not have to empty out or tare the pan on the scale, saving time. Some technicians find the cumulative calculation easier to use as well.

Sieve Size	Cumulative Mass	Cumulative % Retained	%Passing
4.75 mm (#4)	96.8	11.7	88.3
2.00 mm (#10)	383.3	46.2	53.8
0.850 mm (#20)	709.1	85.4	14.6
0.600 mm (#30)	774.4	93.3	6.7
0.425 mm (#40)	801.5	96.6	3.4
0.180 mm (#80)	820.4	98.9	1.1
0.075 mm (#200)	826.5	99.6	0.4
Total	829.8	100.0	

Figure 12. Cumulative method completed.

Non - Cumulative Method

1. Tare the pan on the scale. Weigh the material retained on each sieve (from top to bottom). After the material from each sieve is weighed, empty the tared pan and go to the next sieve. Once all the sieves have been weighed, total the mass (Figure 13).

Sieve Size	Mass	%Ret	%Passing
4.75 mm (#4)	96.8		
2.00 mm (#10)	286.5		
0.850 mm (#20)	325.8		
0.600 mm (#30)	65.3		
0.425 mm (#40)	27.1		
0.180 mm (#80)	18.9		
0.075 mm (#200)	6.1		
Pan	3.3		
Fines Total	**829.8**		

Figure 13. Record mass of material on each sieve individually, and then total the mass.

2. Calculate the % retained by dividing the mass retained on each sieve by the total, and multiplying by 100 (Figure 14). For the 4.75 mm (#4) sieve, that's (96.8 ÷ 829.8) times 100, or 11.7 %. Calculate the % retained for each sieve using the above formula.

Sieve Size	Mass	%Ret	%Passing
4.75 mm (#4)	96.8	**11.7**	
2.00 mm (#10)	286.5	**34.5**	
0.850 mm (#20)	325.8	**39.3**	
0.600 mm (#30)	65.3		
0.425 mm (#40)	27.1		
0.180 mm (#80)	18.9		
0.075 mm (#200)	6.1		
Pan	3.3		
Fines Total	829.8		

Figure 14. Calculate percent of material retained on each sieve individually by dividing the mass of material retained on that sieve by the total mass of the material and multiplying by 100.

3. Once you've calculated the % retained column, add up all the percentages to make sure they equal 100 %. In this example they add up to 100.1 %. In cases where the math gives an odd percentage (either 99.9 or 100.1) increase or decrease the largest percentage in the gradation by 0.1 %. In this example 39.3 was decreased to 39.2 in order to sum up to an even 100 %. (figure 15).

Sieve Size	Mass	%Ret	%Passing
4.75 mm (#4)	96.8	11.7	
2.00 mm (#10)	286.5	34.5	
0.850 mm (#20)	325.8	39.3 ←	change to 39.2
0.600 mm (#30)	65.3	7.9	
0.425 mm (#40)	27.1	3.3	
0.180 mm (#80)	18.9	2.3	
0.075 mm (#200)	6.1	0.7	
Pan	3.3	0.4	
Fines Total	829.8	100.1 ←	100.0

Figure 15. When the percent retained doesn't add up to 100, change the percentage by 0.1 on the sieve which retained the most material.

4. Calculate the % percentage passing for each sieve by cumulatively subtracting the percentage retained on the sieve nested just beneath it (Figure 16).

Sieve Size	Mass	%Ret	%Passing
9.5 mm (3/8")	0.0	0.0	100.0
4.75 mm (#4)	96.8	11.7	88.3
2.00 mm (#10)	286.5	34.5	53.8
0.850 mm (#20)	325.8	39.2	14.6
0.600 mm (#30)	65.3	7.9	6.7
0.425 mm (#40)	27.1	3.3	3.4
0.180 mm (#80)	18.9	2.3	1.1
0.075 mm (#200)	6.1	0.7	0.4
Pan	3.3	0.4	
Fines Total	829.8	100.0	

Figure 16. A cumulative subtraction of the percentages retained from 100 determines the percentage passing for each sieve.

5. Continue the cumulative subtraction all the way down through the last sieve (Figure 17). The % passing the last sieve should be almost equal to the % retained in the pan.

Sieve Size	Mass	%Ret	%Passing
9.5 mm (3/8")	0.0	0.0	100.0
4.75 mm (#4)	96.8	11.7	88.3
2.00 mm (#10)	286.5	34.5	53.8
0.850 mm (#20)	325.8	39.2	14.6
0.600 mm (#30)	65.3	7.9	6.7
0.425 mm (#40)	27.1	3.3	3.4
0.180 mm (#80)	18.9	2.3	1.1
0.075 mm (#200)	6.1	0.7	0.4
Pan	3.3	0.4	
Fines Total	829.8	100.0	

Figure 17. Non-cumulative method completed. Compare these results with Figure 12.

If you compare the results obtained between Figure 12 (Cumulative Method) and Figure 17 (Non-Cumulative Method) you will see that they are the same.

The calculation for the sieve analysis applies to both coarse and fine aggregate samples. Conventionally, fine aggregate samples are weighed to the nearest 0.1 gram, as this example demonstrates. Alternatively, coarse aggregate samples are weighed to the nearest 0.01 kilogram.

NOTE: The following table (Table X1.1) is taken from ASTM C136 Appendix X1. and shows the maximum quantities of aggregate permitted to be retained on individual sieves.

Table X1.1 Maximum Allowable Quantity of Material Retained on a Sieve

Nominal Dimensions of Sieves, mm (in.)					
Sieve Designation, mm (in.)	203.2 (8)	254 (10	304.8 (12 in.)	304.8 x 304.8 (12 x12)	457.2 x 609.6 (18x24)
	Sieving Area, m^2				
	0.028502	0.045730	0.067012	0.092903	0.301935
150	A	A	A	34.84 kg	113.23 kg
125	A	A	A	29.03 kg	94.35 kg
112	A	A	A	26.01 kg	84.54 kg
100	A	A	A	23.23 kg	75.48 kg
90	A	A	15.08 kg	20.90 kg	67.94 kg
75	A	8.57 kg	12.56 kg	17.42 kg	56.61 kg
63	A	7.20 kg	10.55 kg	14.63 kg	47.55 kg
50	3.56 kg	5.72 kg	8.38 kg	11.61 kg	37.74 kg
37.5	2.67 kg	4.29 kg	6.28 kg	8.71 kg	28.31 kg
25.0	1.78 kg	2.86 kg	4.19 kg	5.81 kg	18.87 kg
19.0	1.35 kg	2.17 kg	3.18 kg	4.41 kg	14.34 kg
12.5	0.89 kg	1.43 kg	2.09 kg	2.90 kg	9.44 kg
9.5	0.67 kg	1.09 kg	1.59 kg	2.21 kg	7.17 kg
4.75	0.33 kg	0.54 kg	0.80 kg	1.10 kg	3.59 kg

Note A: Sieves indicated have less than five full openings and should not be used for sieve testing except “Unless a mechanical sieve shaker is used, hand sieve particles larger than 75 mm (3 in.) By determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

COMMON TEST ERRORS

- Insufficient sample size
- Overloading the sieves
- Loss of material transferring material to the tare weighing pan
- Insufficient cleaning of the sieves
- Using worn or cracked sieves
- Thoroughness of sieving
- Pre-drying the sample

QUIZ - TRUE OR FALSE

True or False. If false, correct the statement so it is true.

1. The gradation or sieve analysis test determines the distribution of aggregate particles.

2. Gradation samples must always be dried to a constant mass in an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.).

3. Based on AASHTO specifications, an aggregate sample with a nominal maximum size of 25.0 mm (1") has a minimum sample weight of 10 kg (22 lbs.).

4. ASTM and AASHTO specifications are universal and applicable everywhere.

5. Any 203 mm (8") sieve that retains more than 194 g is considered overloaded.

6. Coarse aggregate entrapped in sieve openings should be gently removed by working it with both hands until it becomes free.

7. Coarse wire brushes are used to clean all 203 mm (8”) sieves.

8. When grading a sample with both fine and coarse aggregate, the fine material retained in the pan always has to be run in its entirety.

9. When grading coarse aggregate, the shaker should always be run for 7 minutes.

10. When grading fine aggregate, the shaker should always be run for 10 minutes.

QUIZ - CALCULATIONS

Calculate the following gradations. Problems 1 and 3 are non-cumulative gradations; and problems 2 and 4 are cumulative gradations.

Problem 1

Sieve Size	Mass	% Retained	% Passing	Specification
25 mm (1")	0.00			100.0
19 mm (3/4")	0.86			
12.5 mm (1/2")	1.78			
6.3 mm (1/4")	2.54			30 - 65
Pan				
Total				

Problem 2

Sieve Size	Cumulative Mass	Cumulative % Retained	% Passing	Specification
25 mm (1")	0.00			100.0
19 mm (3/4")	0.86			
12.5 mm (1/2")	2.64			
6.3 mm (1/4")	5.18			30 - 65
Total	13.44			

Problem 3

Sieve Size	Mass	% Retained	% Passing
4.75 mm (#4)	119.8		
2.00 mm (#10)	333.6		
0.850 mm (#20)	349.8		
0.600 mm (#30)	71.0		
0.425 mm (#40)	30.8		
0.180 mm (# 80)	20.6		
0.075 mm (#200)	9.4		
Pan	56.9		
Total			

Problem 4

Sieve Size	Cumulative Mass	Cumulative % Retained	% Passing
4.75 mm (#4)	119.8		
2.00 mm (#10)	453.4		
0.850 mm (#20)	803.2		
0.600 mm (#30)	874.2		
0.425 mm (#40)	905.0		
0.180 mm (#80)	925.6		
0.075 mm (#200)	935.0		
Total	991.9		

MATERIALS FINER THAN 75 µm (No. 200) SIEVE IN MINERAL AGGREGATES BY WASHING

AASHTO T11

Developed by
Federal Highway Administration Multi-Regional
Aggregate Training and Certification Group

July, 1999

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NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T2, Sampling
- ASTM D3665, Practice for Random Sampling of Construction Materials
- AASHTO T27, Sieve Analysis of Fine and Coarse Aggregate
- AASHTO T248, Reducing Samples of Aggregate to Testing Size

MATERIALS FINER THAN 75 μm (No. 200) SIEVE IN MINERAL AGGREGATES BY WASHING

Scope

Aggregates are the main ingredient in highway construction. They are used in all phases from base construction, pavement mix, granular shoulders, and granular surfacing, as well as, erosion control. In order to ensure the aggregate performs as intended for the specific use, a variety of tests must be performed on the aggregate. One such test is determining materials finer than 75 µm (No. 200) sieve in mineral aggregates by washing. Fine materials such as clay particles or water soluble particles removed by washing, can cling to larger particles and do not dislodge readily. This test washes the fine particles through the 75 µm (No. 200) sieve to give an accurate determination of minus 200 portion in the sample. The determination of minus 75 µm (No. 200) material is used to compare material performance with gradation specifications, and indirectly to gauge such properties as plasticity, permeability, and soils classifications. Such knowledge helps in determining whether a material is frost susceptible or not, and whether permeability (measurement of material capacity to allow water flow through it) will be affected.

Summary of Test

A known amount of material is placed in a wash container and covered with water, agitated to suspend the fine size particles in the water, and then poured through a 75 µm (No. 200) sieve. After thorough rinsing, the portion remaining on the 75 µm (No. 200) sieve is transfered to a pan, dried and weighed. The percentage passing through the 75 µm (No. 200) sieve is then calculated.

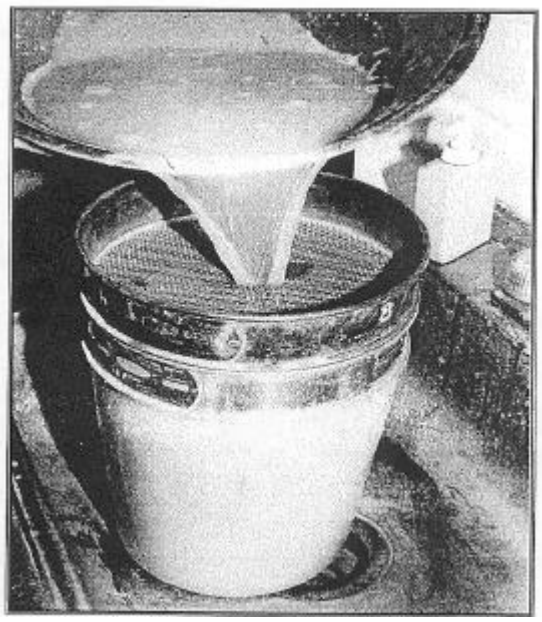

Fig. 1.
Fines suspended in the water are washed over a 2.36 mm (#8) and a 0.075 mm #200 sieve

Apparatus

Balance, general purpose (AASHTO M231)

Sieves, a 2.36 mm (#8) or 1.18 mm (#16) and a 0.075 mm (#200 or 75 μm - 75 micron)

Container, of sufficient size to properly agitate the sample without losing material

Oven, capable of maintaining a temperature of 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.)

Wetting agent, dispersing material such as dish washing soap

Sample Preparation

Dry sample to a constant mass in an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.). Determine the proper dried sample mass from the following table (Table 1) based on the maximum nominal size of the sample to be tested.

Table 1- Sample Mass Requirements

Nominal Maximum Size, mm (in.)	Minimum Weight of Sample, gms (lbs)
2.36 (#8)	100 (0.22)
4.75 (#4)	500 (1.1)
9.5 (3/8)	1,000 (2.2)
19.0 (3/4)	2,500 (5.5)
≥37.5 (1 1/2)	5,000 (11.0)

Procedure

1. Dry sample to a constant mass. Record this as the dry mass of the material to the nearest 0.1 %. Allow sample to air cool until cool to the touch.

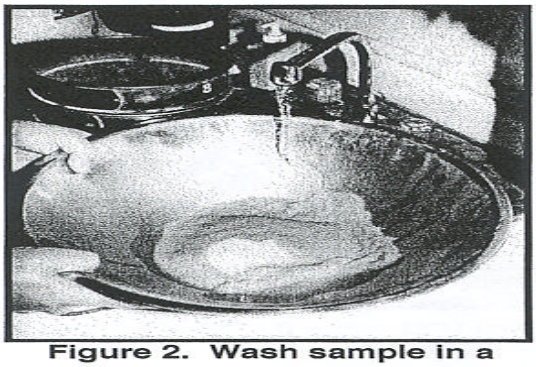

Figure 2. Wash sample in a large washing bowl. Sample should be stirred or agitated in order to suspend the fines in the water.

2. Place sample into a wash container large enough to permit mixing the sample with water (Figure 2). Cover the sample with water (and optionally, at the discretion of the technician, add a small amount of wetting agent) and agitate it with sufficient movement so that the particles finer than the 0.075 mm (#200) sieve become suspended in the water. Stirring and agitating the sample may be necessary and may be accomplished with any stirring or agitating instrument. Care should be taken not to lose any portion of the sample or the fines suspended in the water.

3. Pour the water with the suspended fines through a 0.075 mm (#200) sieve. NOTE: Occasionally inspect the 0.075 mm (#200) sieve for cracks along the seam or holes in the screen, as any imperfections will effect the final wash sieve results. Take care to pour only the water with suspended fines and not the sample itself, since samples with larger size aggregates might damage or clog the fine screen on the 0.075 mm (#200) sieve (Figure 3) Nesting sieves with larger openings (a 2.36 mm - #8, or a 1.18 mm - #16) above the 0.075 mm (#200) sieve might help to prevent inadvertent clogging.

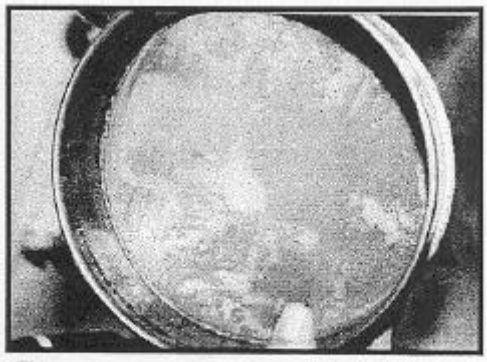

Figure 3. Material retained on the 0.075 mm (#200) sieve after one rinse. Avoid clogging the sieve by dumping the whole sample on it, as it may damage the delicate screen.

4. Continue washing the sample with additional water and agitate until a majority of the fines suspended in the water have been washed through. When the washed sample is near completion the water should be relatively clear compared with the initial water color of the wash sample (Figure 4).

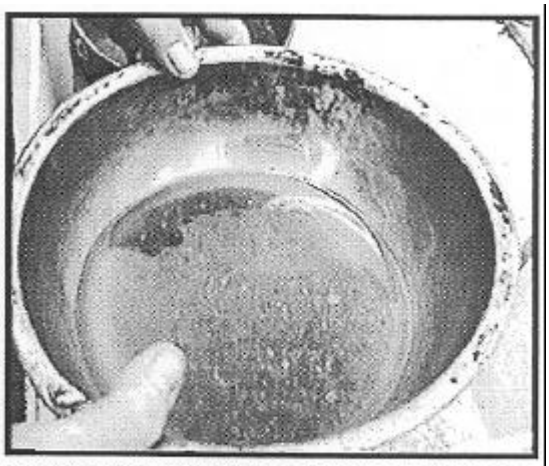

Figure 4. The washed sample should be relatively clear. If you can see the sample beneath the water, then the sample is probably adequately washed.

5. Give the sample a final rinse, pouring as much of the remaining water as possible out of the sample and into the 0.075 mm (#200) sieve. Put the sample remaining in the washing bowl into a pan for oven drying.

6. Any suspended fines remaining on the 0.075 mm (#200) sieve must be included in the sample for drying. Rinsing any suspended fines to one side of the sieve (Figure 5) and then tapping those fines into the pan is one way of accomplishing this. Be sure to include all fines suspended on the 0.075 mm (#200) sieve in the final sample for drying.

It is helpful to use a rinsing bottle (Figure 6) in order to remove the fines sticking to the 0.075 mm (#200) sieve once the sample has been washed.

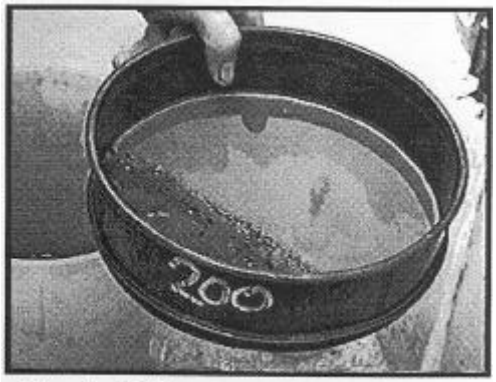

Figure 5. Wash the material retained on the sieve to one side in order to more easily move it to a drying pan.

7. Place the washed sample (Figure 7) into an oven regulated at 110 ± 5 ^{0}C. (230 ± 9 ^{0}F.) and dry to a constant mass. Record the dry mass. Soil is usually placed back in the sieves and graded in accordance with AASHTO T27.

Figure 6
A water bottle is used to wash the material from the 0.075 mm sieve to the drying pan

Figure 7
Sample washed, placed in pan, and labeled.
It will not always be possible to decant all of the water off of the sample

Calculations

Calculate the total % passing the 0.075 mm (#200) sieve (A) by dividing the difference of the original dry sample mass (B) and the mass of sample after washing and drying (C) to a constant mass by the original dry sample mass (B) and multiplying by 100.

$$A = \frac{(B - C)}{B} \times 100$$

Where: A = Total % passing 0.075 mm (#200) sieve
B = Original dry mass of sample (gms), and
C = Dry mass of sample after washing and drying to constant mass (gms)

Example

B = 532.3 gms
C = 521.6 gms
Formula: $A = \frac{B - C}{B} \times 100$

$$A = \frac{(532.3 - 521.6)}{532.3} \times 100$$

A = 2.0 %

Report the percentage of material finer than the 0.075 mm (#200) sieve to the nearest 0.1 %, except if the result is 10 % or more, then report the percentage to the nearest whole number.

Calculations:

Determine the percentage of minus 0.075 mm (#200) for the following samples.

Sample No.	Original Mass	Mass after Wash	Mass Lost	Percentage 0.075 mm (#200)
A	523.2	489.1		
B	564.5	521.2		
C	500.2	498.2		

The following sample was washed and then graded in accordance with AASHTO T27. Determine the total percentage of minus 0.075 mm (#200) material as a part of the overall gradation.

Before Wash	1114.1
After Wash	1050.0
Wash Loss	

Sieve Size	Mass	% Ret.	% Passing
4.75 mm (#4)	124.1		
2.00 mm (#10)	347.8		
0.850 mm (#20)	416.3		
0.600 mm (#30)	86.1		
0.425 mm (#40)	36.8		
0.180 mm (#80)	24.0		
0.075 mm (#200)	13.0		
Pan	4.7+		
Fines Total			

COMMON ERRORS

- Overloading wash sieve.
- Losing sample material when transferring from sieve to weighing pan.
- Splashing material over the sides of the wash container.
- Using a deficient 75 µm (No. 200) sieve, i.e. holes in the screen material or screen material not sealed to the side of the sieve frame.
- Not pre-drying the sample.

Sample Quiz - True or False

1. The wash sieve method is used because it is a much more accurate method for determining the amount of material passing the 0.075 mm (#200) sieve.

2. At least 5,000 gms should be run for the wash sieve for a sample with a nominal maximum size of 19.0 mm (3/4 “).

3. Place the oven dried sample into the wash water immediately after removing from the oven.

4. Agitate the sample with wash water so that the fine material becomes suspended in the water.

5. Pour the entire sample over the 0.075 mm (#200) sieve in order to wash it properly.

6. Nesting sieves with larger openings over the 0.075 mm (#200) sieve may be necessary in order to reduce potential damage to the fine screen.

7. Sieves used for washing (or for any other grading) should be periodically inspected to ensure that the screens are not damaged or cracked in any way.

8. The wash water should be relatively clear during the final rinse of the sample.

9. Once the sample is placed in the drying pan, any remaining fines on the 0.075 mm (#200) sieve may be discarded.

10. Once the washed sample is placed back in the oven and dried to a constant weight, go ahead with the gradation process as usual after recording the new weight of the sample.

Resistance to Degradation of Small Size coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

AASHTO T96

Resistance to Degradation of Large Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

ASTM C535

Developed by
FHWA Multi-regional Aggregate & Certification Group

July, 1999

NOTE

Successful completion of the following training materials, including examination and performance evaluations are prerequisites for this training package.

- AASHTO T96, ASTM C131, Standard Test Method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles machine.
- ASTM C535, Standard Test Method for resistance to degradation of large-size coarse aggregate by abrasion and impact in the Los Angeles machine.

Reference AASHTO Tests

- AASHTO T 2, Sampling Aggregate
- AASHTO T27, Sieve Analysis of Fine and Coarse Aggregate
- AASHTO T248, Reducing Samples of Aggregate to Testing Size

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The Los Angeles Abrasion and Impact Test

Scope

Aggregates are tested in various ways to determine their acceptability for use as a construction material. The Los Angeles (L.A.) Test determines a sample's resistance to abrasion and impact from steel balls in a rotating drum. The resistance to abrasion and impact or "crushing" is measured by the amount of material that is crushed or broken away from each sample particle. There are two methods used, depending on the size of the aggregates. AASHTO T96 (ASTM C131) is used for aggregates smaller than 1 ½ inches. ASTM C535 is used for aggregates larger than 19mm (3/4 inch).

The Los Angeles abrasion test was developed through experience to determines the relative competency or resistance to abrasion an aggregate type has. Aggregate with distinctly different origins should be expected to perform differently in the Los Angeles machine (Figure 1).

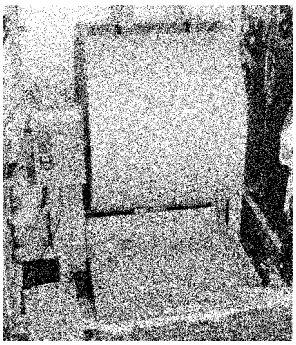


Figure 1 - LA Abrasion Machine

Degradation is a percent loss measurement made on a graded aggregate sample after it has been subjected to abrasion, attrition, impact and grinding in a rotating steel drum (Figure 2) with a specified number of steel spheres.

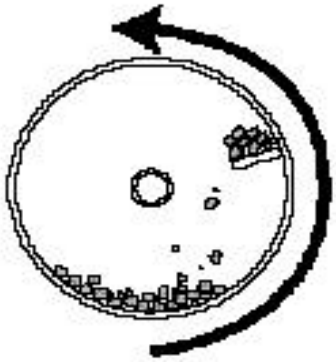
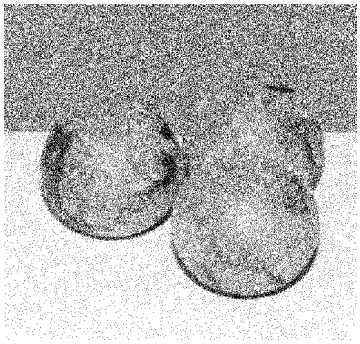


Figure 2 - Rotation of Drum

Apparatus



- Los Angeles Testing Machine: a hollow steel cylinder, with an inside diameter of 711±5 mm (28±0.2 inches).
  See Figure 1 in AASHTO T96 for a more complete description of the apparatus.
- Shelf mounted on inside of drum, 89±2 mm (3.5±0.1") from the opening as measured on the outside of the hollow drum.
- LA machine should be mounted and counterbalanced to provide a uniform peripheral speed of 30 to 33 rpm.

FIGURE 3

- Steel spheres: averaging approximately 46.8 mm (1 27/32 in.) in diameter, each weighing between 390 and 445g (Figure 3). 46, 47.6, 46.8 mm spheres are available and may be used as long as the total number of spheres conforms to the mass requirements for the four grading classes.
- Sieves, in conformance with AASHTO M92, for sieve analysis.
- Balance accurate within 0.1% of test load over the range required for this test (AASHTO M231, Class G5).
- Oven, capable of maintaining 110±5°C (230±9° F).

Procedure

Sample Preparation

Obtain and reduce test sample in accordance with AASHTO T2 and T248.

1. Dry sample to a constant mass.

"Dry the test sample at a temperature of 110±5°C (230±9°F) to a condition where it will not lose more than 0.1 percent moisture after 2 hours of drying. Verify the dry condition by determining the mass of the sample before and after successive 2 hour drying periods.

> **Note:**
> In place of this verification, samples may be considered to have reached constant mass when they have been dried at a temperature of 110±5°C (230±9°F) for an equal or longer period previously found to be adequate to producing the desired constant mass condition when the oven has equal or heavier loading conditions"

2. Separate the sample into individual size fractions, and recombine to the grading of Table 1 or Table 3 that most nearly corresponds to the range of sizes in the aggregate.

Table 1, Grading of Small-Size Test Samples (T96)

Sieve Size, mm (in.)		Mass of Indicated Sizes, grams			
		Grading			
Passing	Retained On	A	B	C	D
37.5 (1 1/2)	25 (1)	1250 ± 25			
25 (1)	19 (3/4)	1250 ± 25			
19 (3/4)	12.5 (1/2)	1250 ± 10			
12.5 (1/2)	9.5 (3/8)	1250 ± 10	2500 ± 10		

9.5 (3/8)	6.3 (1/4)			2500 ± 10	
Sieve Size, mm (in.)		Mass of Indicated Size, grams			
		grading			
6.3 (1/4)	4.75 (#4)			2500 ± 10	
4.75 (#4)	2.35 (#8)				5000 ± 10
TOTAL		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

Table 2, Size of Charge for Small-Size Samples (T96)

Grading	# of Spheres	Mass of Charge, g
A	12.00	5000 ± 25
B	11.00	4584 ± 25
C	8.00	3330 ± 20
D	6.00	2500 ± 15

Table 3, Grading of Large-Size Test Samples (C535)

Sieve Size mm (in)		Mass of Indicated Sizes, g		
		Grading		
Passing	Retained on	1.00	2.00	3.00
75 (3)	63 (2½)	2500 ± 50		
63 (2 1/2)	50 (2)	2500 ± 50		
50 (2)	37.5 (1½)	5000 ± 50	5000 ± 50	
37.5 (1½)	25.0 (1)		5000 ± 25	5000 ± 25
25.0 (1)	19.0 (3/4)			5000 ± 25

TOTAL	10,000 ± 100	10,000 ± 75	10,000 ± 50

SAMPLE TESTING

1. Place the graded sample into the LA Machine. For the small-size samples prepare the required number of steel balls depending on the graded class of the sample being tested. Balls of various sizes and masses may be used, so long as the total mass of the balls is within the tolerances indicated on Table 2 noted above, or as noted below for a large size sample. Make sure that the tight fitting cover is properly in place and bolted down, before you turn on the machine, the speed should be 30 to 33 rpm. For a small size sample the L.A. Machine is set at 500 revolutions.

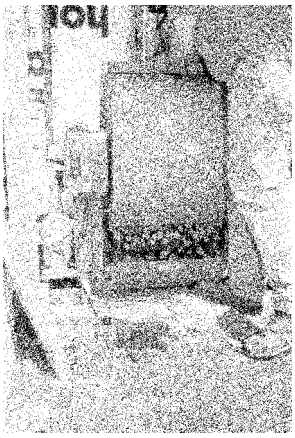


Figure 4 - Discharge of material.

For the large-size sample, 12 balls are used with a total mass of 5000 ± 25g. And rotated for 1000 revolutions.

2. After the prescribed number of revolutions, discharge the material from the machine (Figure 4). Make a preliminary separation of the sample on a 1.70 mm (#12) sieve. Save the material that is larger than the 1.70mm (#12) sieve.

3. For material retained on the 1.70 mm (#12) sieve, grade the sample using AASHTO T27 in addition to washing it over the 1.70 mm (#12). If the material coarser than the 1.70 mm (#12) sieve is essentially free of adherent coatings, then the washing requirement may be waived.

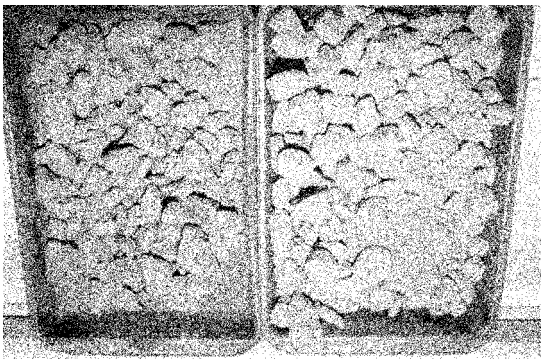


Figure 5 - Before and After testing.

4. Dry material retained on 1.70 mm (#12) sieve to a constant mass in an oven regulated at 110±5°C (230±9° F).

5. Weigh combined aggregate portions to the nearest 1 gram.

Calculations

Express the loss (difference between the original mass and the final mass of the test sample) as percentage of the original mass of the test sample. The method calculating the loss is the same for coarse or fine aggregate sizes.

$$\text{LA Abrasion} = 100\,[(a-b)/a],$$

where a = original sample mass
b = mass after test

EXAMPLE
Material Grade “B”

Weight of combined material (original sample mass) = 5003 g (a)

Weight of combined material (mass after test) = 4012 g (b)

$$\text{LA Abrasion} = 100 \times \frac{5003 - 4012}{5003} = 19.8\%$$

Common Testing Errors

- Sample not representative
- Not using correct number of spheres
- Mass of all spheres not within tolerances
- Not drying sample to a constant mass
- Not setting or re-zeroing counter
- Not cleaning out all of material in drum

GLOSSARY

Steel Spheres - Round steel balls approximately 46.8 mm in diameter.

Constant Mass - The mass at which a sample will lose less than 0.1% moisture after 2 hours of drying.

Charge - The number of steel spheres based on the grading of material.

Small-Size Coarse Aggregate - Material smaller than 37.5 mm (1½ in.) (AASHTO T96 & ASTM C 131).

Large-Size Coarse Aggregate - Material larger than 19 mm (¾ in.) (ASTM C 535).

Degradation - Reduction in size of material caused by L.A. Abrasion testing.

Original Mass - Weight of sample before being tested.

Final Mass - Weight of material after testing, washing, sieving, and drying.

CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATE

AASHTO T 112

Developed by
FHWA Multi-Regional Aggregate Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- ASTM D 3665, Method of Random Sampling
- AASHTO T 2, Sampling of Aggregates
- AASHTO T 248, Reducing Samples of Aggregate to Testing Size
- AASHTO T 27, Sieve Analysis of Coarse and Fine Aggregates
- AASHTO T 11, Amount of Materials Finer Than 75μm Sieve in Aggregate

GLOSSARY

Friable Particles - Aggregate particles easily broken up.

Coarse Aggregate - Normally an aggregate consisting of particles predominately larger than a 4.75 mm (#4) sieve. For the purposes of this test method, coarse aggregate is defined as any aggregate sample containing 50 percent or more particles retained on the 4.75 mm (#4) sieve.

Fine Aggregate - An aggregate sample with predominately material which will pass the 4.75 mm (#4) sieve.

Combined Aggregate - An aggregate containing both coarse and fine particles in a relatively even amount.

CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATE

Aggregate is one of the largest components in highway construction. To ensure the aggregate used performs as intended, several tests are performed to determine the physical characteristics of the material. One of these tests is the determination of Clay Lumps and Friable Particles in Aggregate.

Excessive clay lumps in a processed aggregate intended for use in a Portland Cement or Hot Mix Asphalt may interfere with the bonding between the aggregate and cementitous material. This will result in spalling, raveling, or stripping and create weak points and pop-outs if the material is incorporated into the pavement or structure.

Aggregate intended to perform as a drainable base or subbase may also be adversely affected when excess amounts of clay and friable particles are present. This type of material tends to fill the void spaces intended for drainability, eventually contributing to pavement failure.

Attaining a reasonably accurate determination of the amount of clay lumps and friable particles in the processed aggregate is dependent on properly obtaining samples representative of the lot or sublots.

SUMMARY OF TESTING

There are two test methods for determining the clay lumps and friable particles in aggregates. There is a method for coarse aggregate and one for fine aggregate. The test methods are similar, but there are differences, so always be sure to follow the correct method for the type of aggregate being tested.

The material is sampled, dried, and soaked according to testing instructions. The clay lumps and friable particles are broken down by manipulation, using the thumb and forefinger. The material is washed, dried, and sieved according to the correct test procedure.

The materials are weighed and the calculations for the percent of clay lumps and friable particles are performed.

Common Testing Errors

- Test samples are not representative of the product.
- Improper coarse aggregate sample preparation.
- Failure to perform AASHTO T 11 before determining Clay Lumps and Friable Particles.
- Incorrect determination of the percent of Clay Lumps and Friable Particles in a coarse aggregate sample.
- Failure to use the roll and squeeze method when attempting to break particles down.
- Improper drying procedures.

TEST METHODOLOGY - FINE AGGREGATE

Apparatus

- Balance - The balance shall have sufficient capacity to determine the mass of the test samples, be accurate to 0.1 percent of the mass of the sample to be tested, and conform to the requirements of AASHTO M 231.

- Containers - Rust-resistant containers of a size and shape that will permit the spreading of the sample on the bottom in a thin layer.

- Sieves - Sieves conforming to AASHTO M 92.

- Oven - An oven (or drying stove) capable of providing free circulation of air and capable of maintaining a temperature of 110°∓5°C (230°∓9°F).

Sample Preparation

First subject the test sample to AASHTO T 11, Amount of Material Finer Than the 75 μm (No. 200) Sieve in Aggregate.

The sample shall be dried to a constant dry mass at a temperature of 110°∓5°C (230°∓9°F).

Remove the material smaller than 1.18 mm (No. 16) sieve by thoroughly sieving the original sample over the 1.18 mm (No. 16) sieve. The mass retained on this sieve is the test sample and must be at least 100 grams.

Test Procedure

Weigh the test sample and spread it in a thin layer on the bottom of an appropriately sized, rust-resistant container, cover the sample with water and allow it to soak for a period of 24∓4 hours.

Decant the excess water from the sample after soaking. Roll and squeeze individual particles between the thumb and forefinger to attempt to break the particle into smaller pieces. Do not use fingernails, nor press the particles against hard surfaces or each other in the attempt to break the particles.

After all discernable clay lumps and friable particles have been broken, sieve the sample on an 850 μm (No. 20) sieve and then place it in a suitable drying pan. Dry the sample to a constant dry mass at a temperature of 110°∓5°C (230°∓9°C). Allow the sample to cool and weigh the sample to the required accuracy specified for the balance in AASHTO M 231.

Calculations

Calculate the percent of clay lumps and friable particles in fine aggregate using the following formula:

$$P = \{(W-R)/W\} \times 100$$

where:

P = percent of clay lumps and friable particles

W= mass of test sample (for fine aggregate this is the portion retained on the 1.18 mm (No. 16) sieve)

R = mass of material retained on the 850 μm (No. 20) sieve

Note: *Follow the rounding rules specified by your state.*

TEST METHODOLOGY (COARSE AGGREGATE)

Apparatus

The same apparatus is used for the coarse aggregate test method that is used for the fine aggregate test method.

Sample Preparation - Coarse Aggregate

Subject the sample to be tested to AASHTO T 11, Amount of Material Finer Than 75 μm (No. 200) Sieve.

The aggregate sample shall be dried to a constant mass at a temperature of 110°∓5°C (230°∓9°F).

Separate the coarse aggregate sample into individual fractions using the following sieves to obtain the minimum masses as shown below in Table 1:

Sizes of Particles Making Up Test Sample	Min. Mass of Individual Test Sample, Grams
4.75 mm to 9.5 mm (No. 4 to d in.)	1000
9.5 mm to 19.0 mm (d in. to ¾ in.)	2000
19.0 mm to 37.5 mm (¾ in. to 1½ in.)	3000
Over 37.5 mm (1½ in.)	5000

Table 1

Note: *To provide the minimum required individual masses as indicated in the above chart, it may be necessary to combine the material from more than one test by AASHTO T 11. If the original grading of the sample has less than 5% of material retained on any of the above individual sizes, do not test that size.*

Test Procedure - Coarse Aggregate

Weigh each fraction size and spread the individual samples in rust-resistant pans to form a thin layer.

Cover the samples with water and soak for 24∓4 hours.

Sample Soaking

After soaking, decant the excess water from the samples. Roll and squeeze suspect particles between the thumb and forefinger to attempt to break the particles into smaller sizes. Do not use fingernails to break the particles, or press the particles against a hard surface or each other.

Attempting to Break Particles

After all recognizable clay lumps and friable particles have been broken, remove the undersized material from each tested fraction by wet-sieving. The wet-sieving is to be accomplished by placing the sample on the appropriate size sieve for the size of the individual fraction (as shown in Table 2) and passing water over the sample while manually agitating the sieve, until all undersize material has passed the required sieve.

Size of Particles Making Up the Sample	Sieve Size for Removing Residue of Clay Lumps and Friable Particles
4.75 mm to 9.5 mm (No. 4 to d in.)	2.36 mm (No. 8)
9.5 mm to 19.0 mm (d in. to ¾ in.)	4.75 mm (No. 4)
19.0 mm to 37.5 mm (¾ in. to 1½ in.)	4.75 mm (No.4)
Over 37.5 mm (1½ in.)	4.75 mm (No. 4)

Table 2

The material that can be broken down and removed from the sample by wet-sieving is classified as clay lumps and friable particles.

Remove the retained particles carefully from the sieve. Dry the sample to a constant dry mass at 110°∓5°C (230°∓9°F), and allow the material to cool.

Weigh and record the mass of the material to the accuracy specified for the balance in AASHTO M 231.

NOTE

Combined aggregates (those containing a substantial amount of coarse and fine material) are separated into two fractions using the 4.75 mm (No .4) sieve and then prepared as appropriate for the correct size of the material (i.e., coarse or fine aggregate). Any aggregate containing 50% or more retained on the 4.75 mm (No. 4) sieve is considered a coarse aggregate.

In most cases, only the plus 4.75 mm (No. 4) fraction of coarse aggregate needs to be evaluated by this test method regardless of the amount of minus 4.75 mm (No. 4) material present. However, the amount of material between the 1.18 mm (No. 16) and 4.75 mm (No. 4) sieves is included in the mass of the test sample when calculating the percent of clay lumps and friable particles.

Calculations

Calculate the percent of clay lumps and friable particles in the individual sizes as follows:

$$P = \{(W-R)/W)\} \times 100$$

where:

P = percent of clay lumps and friable particles

W = mass of test sample (this is the mass of each size increment prepared for test)

Note: *include the mass of the plus 1.18 mm (No. 16) to minus 4.75 mm (No. 4) when needed, if the aggregate contains both coarse and fine particles.*

R = mass of particles retained on a designated sieve

The percent of clay lumps and friable particles in coarse aggregate is an average based on the percent of clay lumps and friable particles in each sieve size fraction weighed in accordance with the grading of the original sample, or preferably the average grading of the entire lot. When the sample contains less than 5% of the total material in a given size, based on the original grading of the aggregate sample, that increment is considered to have the same percent of clay lumps and friable particles as the next larger or smaller fraction, whichever is present (see Table 3).

Particle Size	Original Sample Percent Retained	Percent Clay Lumps and Friable Particles	Weighted Average Percent
4.75 mm to 9.5 mm (No. 4 to d in.)	24	13	3.12
9.5 mm to 19.0 mm (d in. to ¾ in.)	15	8	1.20
19.0 mm to 37.5 mm (¾ in. to 1½ in.)	4	8*	0.32
Total Percent in aggregate			4.64

*the percent of material retained on the fraction from 19.0 mm (¾ in.) to 37.5 mm (1½ in.) is less than 5 percent, therefore the percent of clay lumps and friable particles found to be in the next smaller size increment (8%) is used in the weighted average.

Table 3

PLASTIC FINES IN GRADED AGGREGATE AND SOILS BY USE OF THE SAND EQUIVALENT TEST

AASHTO T176

Developed by
FHWA Multi-regional Training & Certification Group

July 1999

Note:

Successful completion of the following training materials, including examination and performance evaluations are prerequisites for this training package.

- AASHTO T 176, Standard method of Testing for Plastic Fines in Graded Aggregate and Soils By Use of Sand Equivalent Test.

Reference AASHTO Tests

- AASHTO T 2, Standard Practice for Sampling Aggregate
- AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
- AASHTO T 248, Reducing Samples of Aggregate to Testing Size

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Plastic Fines in Graded Aggregate and Soils by Use of the Sand Equivalent Test

Scope

The Sand Equivalent Test uses a liquid solution to separate the clay-like material (fine dust) from the larger material in a sample that passes the No. 4 sieve. Once the clay-like material is separated the percent or amount of material in a sample that has similar characteristics to sand can be determined. A higher sand equivalent value indicates that there is less clay-like material in a sample. Clay-like materials have a direct effect on the performance of Hot Mix Asphalt (HMA) and the amount should be controlled to provide quality bituminous mixtures. A large amount of clay-like particles can coat the aggregate surfaces and prevent the liquid asphalt from completely coating and adhering to the aggregate.

Apparatus

The following equipment is needed to perform the sand equivalent test. The equipment needs to conform to the specifications and dimensions of the standard test method. Additional accessory items are also noted in a list of materials in the stan dard test method.

- A plastic graduated cylinder with a rubber stopper.
- Irrigation Tube
- Weighted foot assembly
- Siphon assembly
- Tinned Measure
- Wide-Mouth Funnel
- A clock or watch
- A mechanical or manual shaker
- Bottle of solution

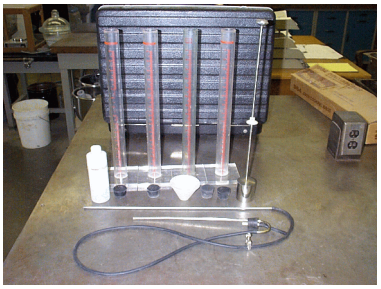

Figure 1 - Graduated Cylinder, Irrigation Tube, weighted foot Assembly and Siphon.

Note:
The solution is placed on a shelf 915 mm±25 mm (36 in.±1 in.) Above the work surface.

Figure 2 - Mechanical Shaker

Summary of Test

The sand equivalent value of a prepared sample is determined by placing the sample into a graduated cylinder with the test solution. After the sample has soaked, the cylinder is capped off or sealed. The cylinder is then shaken in a horizontal position to completely mix the sample and solution.

There are three separate methods that can be used to shake a sample. The preferred or recommended method is the method using a mechanical shaker. The other two, the manual shaker or the hand method can be used, but each one has specific requirements that must be maintained to obtain accurate results.

When the mixing is finished the cylinder is stood upright, irrigated and allowed to stand undisturbed. The sample will sink toward the base of the cylinder. The heavier particles will sink to the bottom of the cylinder rapidly and the suspended fine material will slowly settle toward the bottom. After 20 minutes $\pm$ 15 sec. the top of the suspended material is noted as the clay reading. The sand reading is noted after a weighted assembly is lowered into the cylinder and it comes to rest on the surface of the sand or coarse material that has settled out. Once the readings are obtained a simple calculation is used to determine the sand equivalent value.

Test Precautions

This test method has numerous steps where errors can be introduced, unless certain details are carefully controlled or monitored before and during the test procedure. The prepared solution of calcium chloride, glycerin and formaldehyde solution should be mixed, used and maintained with care. The Material Safety Data Sheets should be used for any safety issues associated with this test when using the noted solution.

Most of the precautions are associated with good laboratory techniques and watching the details. The sample preparation and the shaking of the sample have specific requirements that are needed for accurate test procedures, and test results.

Sample Preparation

The test is conducted on soils or graded aggregate passing the 4.75mm (No. 4) sieve. When separating the sample special care should be made to collect all the minus 4.75mm (No. 4) material. Any clumps or dust should be broken apart and included with the material passing the 4.75mm (No. 4) sieve.

Split the sample into the desired number of test samples, with enough material to slightly overfill the tin measure. Set up each test sample by either one of the alternate methods

described in the standard specification, or the referee method (mechanical shaker).

Test Procedure

The following step by step procedure for the mechanical shaker (Referee Method) is recommended to understand the laboratory techniques needed for accurate test results.

1. Allow the initial sample to air dry.

2. Split or quarter the sample until you have slightly more material than it will take to fill a 3 ounce tin cup. The tin cup is in the case marked SAND EQUIVALENT.

3. Place the tin cup in a larger flat container. A bread pan will work.

4. Take the sample obtained by splitting or quartering and slowly pour the sample into the tin cup.

5. As you pour the sample, gently tap the bottom edge of the tin cup on a hard surface (the bottom of the large flat container will work.)

6. After filling, strike off the top of the tin cup with a straight edge.

7. Remove one of the plastic graduated cylinders from the case marked “SAND EQUIVALENT”.

8. Place the cylinder on the sink by the siphon assembly.

9. Siphon 4.0+/-0.01 inches of working calcium chloride solution into the cylinder.

10. Pour the content of the tin cup into the solution.

11. Tap the bottom of the cylinder several times with the heel of your hand to help release trapped air bubbles and promote thorough wetting of the sample.

12. Let the cylinder and sample stand undisturbed for 10 +/-1 minutes.

13. Place the rubber stopper in the cylinder.

14. Loosen the material from the bottom of the cylinder.

15. Place the cylinder in the Mechanical Shaker.

16. Tighten the screw to hold the cylinder.

17. Turn the Mechanical Shaker on.

18. BE SURE TO HOLD THE MECHANICAL SHAKER IN PLACE, IF IT HAS NOT BEEN

ANCHORED TO A FIRM FLAT SURFACE.

19. When the shaker is finished, loosen the screw.

20. Remove the cylinder.

21. Remove the stopper.

22. Place the cylinder on the sink by the siphon assembly.

23. Remove the irrigation tube from the glass.

24. Place the irrigation tube into the cylinder.

25. Loosen the restraints on the siphon tube.

26. Rinse the material from the cylinder walls as you lower the tube into the cylinder.

27. Force the irrigation tube through the sample.

28. Twist the irrigation tube.

29. Keep forcing and twisting the tube through the sample.

30. Keep doing this until the fluid level reaches approximately 15 inches.

31. Raise the tube, keeping the fluid level at the 15 inch mark.

32. Replace the restraints on the siphon tube.

33. Allow the cylinder and sample to stand undisturbed for 20 minutes +/- 15 seconds.

34. After this time take the Clay reading.

35. Read the top of the Clay suspension. (See Figure 4) If the suspension level between lines take the highest reading.

36. Insert the weighted foot assembly. (Refer to the standard test method for specific notes of the weighted foot assemblies.)

37. MAKE SURE THAT YOU DO NOT ALLOW THE INDICATOR TO HIS THE MOUTH OF THE CYLINDER.

38. Lower the assembly into the solution until the foot comes to rest on the sand.

39. Take the sand reading. If the indicator is between 2 lines take the highest reading. (See figure 5.)

40. Record the clay and sand readings.

41. Enter the clay and sand readings in the Sand Equivalency formula and complete the calculations.

Calculations

Calculate the sand equivalent (SE) value to the nearest 0.1 using the following formula:

$$SE = \frac{Sand\ \mathrm{Re}ading x 100}{Clay\ \mathrm{Re}ading}$$

Common Testing Errors

- Calcium Chloride Solution not mixed properly, used outside of the temperature range or not checked for organic growth.
- Vibrations or jarring while sample is settling out in the solution.
- Improper sample preparations (splitting & test sample preparations.)
- Solution exposed to direct sunlight.
- Sample not irrigated correctly.
- Sample not shaker properly in graduated cylinder.

GLOSSARY

Irrigation Tube - Metal tube pushed thru material to help force clay-like material into suspension.

Weighted Foot Assembly - Device used to measure the height of the nonclay-like material.

Siphon Assembly - A gallon container and flexible hose used to introduce the solution into the irrigation tube.

Mechanical Shaker - Used to agitate the sample and solution before irrigation.

Quiz

1. The material shall pass what sieve?

2. Do we use air dried or pre-wet material?

3. How much solution is siphoned into the graduated cylinder before the sample is added?

4. How long is the wetted sample allowed to stand undisturbed before shaking?

5. The irrigation procedure is performed until the solution reaches what height in the graduated cylinder?

6. How long does the cylinder and contents stand undisturbed before you take your readings?

7. What do you do with the readings that fall between the graduations on the graduated cylinder?

SPECIFIC GRAVITY OF COARSE AGGREGATE

AASHTO T 85

Developed by
FHWA Multi-Regional Aggregates Training & Certification Group

July, 1999

Note

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package

AASHTO T27 - Sieve Analysis of Fine and Coarse Aggregate
AASHTO T248 - Reducing Samples of Aggregate to Testing Size

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AASHTO T85 Specific Gravity of Coarse Aggregates

AASHTO T85-Specific Gravity of Coarse Aggregates

Summary of Procedure

Specific Gravity is the ratio of the mass of a given volume of aggregate to the mass of an equal volume of water. Water, at a temperature of 23º C (73.4º F) has a specific gravity of "1" or 1000 kg per cubic meter. Specific Gravity is important for several reasons. Some deleterious particles are lighter than the good aggregates. Tracking specific gravity can sometimes indicate a change of material or possible contamination. Differences in specific gravity can be used during production to separate the bad particles from the good using a heavy media liquid.

Specific gravity is critical information for the asphalt mix design Engineer. It is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt. All are critical to a well performing and durable asphalt mix. Water absorption can also be an indicator of asphalt absorption. A highly absorptive aggregate could lead to a low durability asphalt mix.

In Portland Cement Concrete the specific gravity of the aggregate is employed in calculating the percentage of voids and the solid volume of aggregates in computations of yield. The absorption is important in determining the net water-cement ratio in the concrete mix. Knowing the specific gravity of aggregates is also critical to the construction of water filtration systems, slope stabilization projects, railway bedding and many other applications.

This method determines the specific gravity of coarse aggregates that have been soaked for a period of 15-19 hours. (Figure 1). There are four determinations that may be made from this procedure. They are as follows:

Figure 1, Coarse Aggregate Gravity Apparatus

A. Bulk specific Gravity (Gsb) (also known as Bulk Dry Specific Gravity)

The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at a stated temperature (Figure 2). This unit volume of aggregates is composed of the solid particle, permeable voids and impermeable voids.

The formula for Gsb is as follows:

Gsb = A / (B – C)

Where: A = Oven dry mass.
B = SSD mass.
C= Mass in water

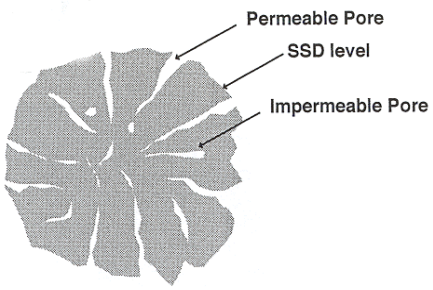


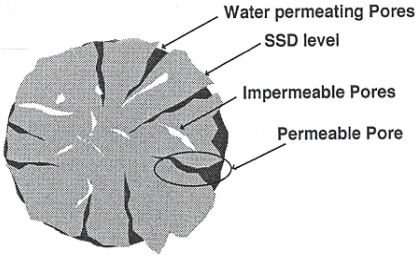
Figure 2. Diagram of Bulk Specific Gravity.

B. Bulk SSD Specific Gravity (Gsb SSD)

The ratio of the mass in air of a unit volume of aggregate, INCLUDING the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the mass in air of an equal volume of gas-free distilled water at a stated temperature (Figure 3).

The formula for Gsb SSD = B / (B – C)

Where: A = Oven dry mass.
B = SSD mass.
C= Mass in water



SSD weight is the Saturated Surface Dry condition and includes the permeable pore space

Figure 3. Diagram of Bulk SSD Specific Gravity.

C. Apparent Specific Gravity (Gsa)

This ratio of the mass in air of a unit volume of the IMPERMEABLE portion of aggregate (does not include the permeable pores in aggregate) to the mass in air of an equal volume of gas-free distilled water at a state temperature (Figure 4).

The formula for Gsa = A / (A – C)

Where: A = Oven dry mass.
B = SSD mass.
C= Mass in water

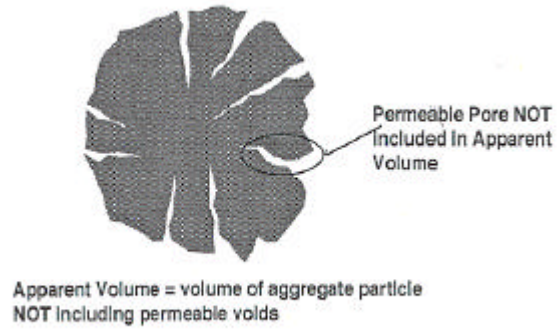


Figure 4. Diagram of Apparent Specific Gravity.

D. Absorption (% Abs.)

The increase in mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles (Figure 5.)

%Abs. = [(B – A) / A] x 100

Where: A = Oven dry mass. B = SSD mass. C= Mass in water

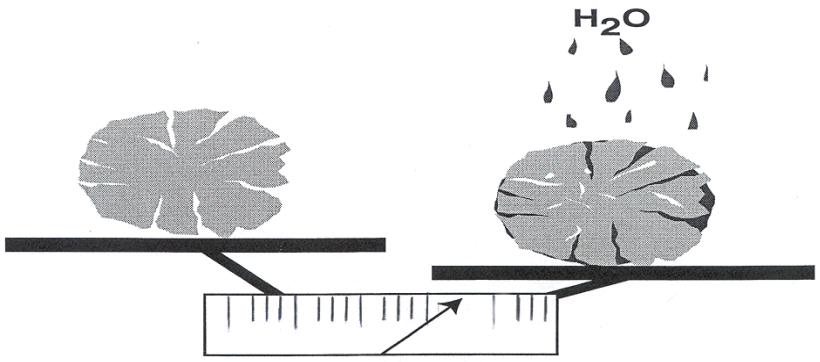


Figure 5, Increase in mass due to absorption of water

Common Testing Errors

- Improper identification of SSD, i.e. over or under-drying.
- Air entrapped in suspended sample or sample immersion container.
- Suspension apparatus in contact with another object, resulting in false readings.
- Loss of material during transfer to the drying pans.
- Weighing errors (i.e. Improper Tare weights or loss of material)

. . . . . .

Apparatus

- Balance, conforming with class G5 (AASHTO M231)
- Sample container, wire basket of 3.35 mm (6#) or less mesh wire cloth, with a capacity of 4 to 7 L to contain aggregate with a nominal maximum size of 37.5 mm (1 ½") or smaller; larger basket for larger aggregates.
- Water tank, watertight and large enough to completely immerse aggregate and basket, equipped with an overflow valve to keep water at a constant level.
- Suspended Apparatus, wire used to suspend apparatus shall be of smallest practical diameter. A hi-test fishing leader or other thin wire with utility hook can be used with a small hook attached to the handle of the basket or sample container.
- Sieves, 4.75 mm (#4) or other size as needed, conforming to AASHTO M92.

Procedure

Thoroughly mix the sample and reduce it to sample size (Figure 6) in accordance with AASHTO T248 (Reducing Field Samples of Aggregate to Test Size). Use sample sizes as indicated in Table 1.

Figure 6. Reduce sample to test size using applicable procedure.

2. Dry sieve the sample through a 4.75 mm (#4) sieve and discard any material that passes the sieve. NOTE: if a substantial amount of material passes the 4.75 mm (#4) sieve, you may need to use a 1.18mm (#8) sieve instead of the 4.75 mm (#4), OR you may need to perform a specific gravity on minus 4.75 mm (#4) material. Wash the aggregate retained on the 4.75 mm (#4)

TABLE 1.

Nominal Maximum size	Minimum Sample Mass
12.5 mm (1/2”)	2 kg/ 4.4 lbs.
19 mm (3/4”)	3 kg/ 6.6 lbs.
25 mm (1”)	4kg/ 8.8 lbs.
37.5 mm (1 ½”)	5kg/ 11 lbs.
50mm (2”)	8 kg/ 18 lbs.
63 mm (2 ½”)	12 kg/ 26 lbs.
75 mm (3”)	18 kg/ 40 lbs.

3. Dry Test sample to constant mass in an oven regulated at 110 ± 5 °C (230±9 °F). Cool sample at room temperature for 1 to 3 hrs. After the cooling period, immerse the aggregate in water at room temperature for a period of 15 to 19 hrs.

4. Remove the sample from soaking and drain any excess water from the aggregate. Using an absorbent cloth (an absorbent towel usually works best), roll the aggregate until the surface water has been removed. Rolling up the aggregate into the towel sausage style and then shaking and rolling the aggregate from side to side is usually effective in reducing the sample to an SSD (saturated, surface-dry) condition (Figure 7).

Figure 7

The sample may be contained in the rolled cloth and shaken until it achieves an SSD condition. An SSD condition is one in which the aggregate has no FREE water on its surface (Figures 8 & 9).

Figure 8

Figure 9

5. Weigh SSD sample to nearest 1.0g or 0.1% of the total mass, whichever is greater and record this as SSD mass.

6. After weighing, place entire sample in container and weigh in water maintained at 23 ± 1.7 °C (73.4 ± 3 °F). Shake container to release any entrapped air and weigh on minimum diameter wire suspended below scale apparatus. Ensure that the overflow is working properly to compensate for the water displaced by the sample (Figure 10). Record to the nearest 1.0 g or 0.1 % of total mass, whichever is greater, as the mass in Water (C).

Figure 10

7. Remove the test sample from the water and the container and dry in a pan to a constant mass in an oven regulated at 110 ± 5 °C (230 ± 9°F). cool in air at room temperature for 1 to 3 hrs., or until the aggregate can be comfortably handled. Record mass to nearest 1.0 g or 0.1%, whichever is greater, as oven dry mass.

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Calculations:

Determine calculations based on appropriate formula for desired result. A = Oven dry mass., B = SSD mass., C = Mass in water.

A. Bulk Specific Gravity (Gsb) **Gsb = A / (B-C)**

B. Bulk SSD Specific Gravity (Gsb SSD) **Gsb SSD = B / (B-C)**

C. Apparent Specific Gravity (Gsa) **Gsa = A / (A-C)**

D. Absorption (%Abs.) **%Abs. = [(B – A) / A] x 100**

Instructors Note: It is best to perform at least two trials of each sample (three trials are preferred). Compare the results of each trial to the single operator precision and bias statement. If the results compare favorably, an average of the two may be reported. If the results do not meet the precision and bias criteria, the calculations and data should be rechecked for errors.

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Example Calculations for Coarse Aggregate

Trial	A	B	C	B-C	A-C	B-A
1	2030.9	2044.9	1304.3	740.6	726.6	14.0
2	1820.0	1832.5	1168.1	664.4	651.9	12.5
3	2035.2	2049.4	1303.9	745.5	731.3	14.2

Trial	Bulk SSD B/B-C	BULK A/B-C	APPARENT A/A-C	ABS. (B-A/A)100
1	2.761	2.742	2.795	0.691
2	2.758	2.739	2.792	0.698
3	2.749	2.730	2.783	0.698
Ave.	2.756	2.737	2.790	0.693

A = Weight of Oven Dry Specimen in Air
B = weight of SSD Specimen in Air
C = Weight of SSD Specimen in Water

These calculations demonstrate the relationship between Gsb, Gsb SSD, and Gsa; in that the Gsb (bulk specific gravity) will always be the lowest value since the volume calculated includes voids permeable to water, the Gsb SSD (Bulk specific gravity at SSD) will always be the intermediate value, and the Gsa (Apparent specific gravity) will always be the highest, since the volume calculated concerns only the “solid” aggregate particle (does not include those voids permeable to water). When running this test check to make sure the values calculated make sense in relation to one another.

Its also a good idea to check the precision statement in the AASHTO T85, Table 1. Precision statements enable you to check your test results for the acceptable tolerances amongst themselves and to check your numbers against those numbers determined by another lab or agency on the same material.

Quiz

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Specific Gravity of Coarse Aggregate

True or False.

1. Bulk specific gravity is the determination of the specific gravity including air voids or pores permeable to water that exist within the aggregates.

2. Absorption is measured by checking the increase in weight of an aggregate as water is absorbed by an aggregate's permeable pore spaces. This determination is made at SSD.

3. Apparent specific gravity measures the specific gravity of the aggregate as if it had no permeable pores or voids within the aggregates.

4. According to AASHTO, a sample with a nominal maximum size of 25 mm (1") should use 4 kg (8.8 lbs.) for the specific gravity test.

5. When performing a specific gravity test on coarse aggregate, sieve the material over a 9.5 mm (3/8") screen and discard any minus 9.5 mm (3/8") material.

6. The 24 hr. soaking period must be stringently followed in all situations.

7. An SSD condition exists when the aggregates surface is visibly wet.

8. The determination of the 'dry weight' of aggregate is made prior to the determination of the wet weight.

9. Specific gravity samples should be weighed immediately as they are removed from the oven.

10. The drying to a constant weight requirement for coarse aggregate may be eliminated if the aggregates have been kept continuously wet and are to be used in a moist condition.

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Calculation Exercise

Specific Gravity of Coarse Aggregate

Example Calculations
Fill in the following chart.

Trial	A	B	C	B-C	A-C	B-A
1	**2328.2**	**2341.1**	**1503.5**			
2	**2177.2**	**2188.5**	**1402.3**			
3	**2028.3**	**2040.2**	**1309.7**			

Trial	BULK SSD B/B-C	BULK A/B-C	APPARENT A/A-C	ABS. (B-A/A)100
1				
2				
3				
Ave.				

A = Mass of Oven Dry Specimen in Air
B = Mass of SSD Specimen in Air
C = Mass of SSD Specimen in Water

Glossary

Absorption: The increase in mass due to water contained in the pores of the material.

Bulk Specific Gravity (also known as Bulk Dry Specific Gravity): The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

Bulk SSD Specific Gravity: The ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

Apparent Specific Gravity: The ratio of the mass in air of a unit volume of the impermeable portion of aggregate (does not include the permeable pores in aggregate) to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

SSD – Saturated, Surface Dry. The condition in which the aggregate has been soaked in water and has absorbed water into its pore spaces. The excess, free surface moisture has been removed so that the particles are still saturated, but the surface of the particle is essentially dry.

SPECIFIC GRAVITY OF FINE AGGREGATES

AASHTO T 84

Developed by
FHWA Multi-Regional Aggregates Training & Certification Group

July, 1999

Prerequisites

AASHTO T27 - Sieve Analysis of Fine and Coarse Aggregate

AASHTO T248 - Reducing Samples of Aggregate to Testing Size

Table of Contents

AASHTO T84 Specific Gravity of Fine Aggregates

Basic Information Scope

Specific Gravity is the ratio of the mass of a given volume of aggregate to the mass of an equal volume of water. Water, at a temperature of 23º C (73.4º F) has a specific gravity of "1" or 1000 kg per cubic meter. Specific Gravity is important for several reasons. Some deleterious particles are lighter than the "good" aggregates. Tracking specific gravity can sometimes indicate a change of material or possible contamination. Differences in specific gravity can be used to separate the bad particles from the good using a heavy media liquid.

Specific gravity is critical information for the Hot Mix Asphalt Design Engineer. It is used in calculating air voids, voids in mineral aggregate (VMA), and voids filled by asphalt. All are critical to a well performing and durable asphalt mix. Water absorption can also be an indicator of asphalt absorption. A highly absorptive aggregate could lead to a low durability asphalt mix.

In Portland Cement Concrete the specific gravity of the aggregate is employed in calculating the percentage of voids and the solid volume of aggregates in computations of yield. The absorption is important in determining the net water-cement ratio in the concrete mix. Knowing the specific gravity of aggregates is also critical to the construction of water filtration systems, slope stabilization projects, railway bedding and many other applications.

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Summary of Procedure

This method determines the specific gravity of fine aggregates that have been soaked for a period of 15-19 hours. The determinations that may be made from this procedure are identical to those made under AASHTOT85 (Specific Gravity and Absorption of Coarse Aggregate).

Common Testing Errors

Improper Pycnometer calibration

Air entrapped in sand leading to false weight measurement, due to volume of pycnometer occupied by air.

Improper surface moisture test due to one or more of the following:

Improper drop of tamper (too high or too low during compaction into the cone)

Insufficient timing of test. Testing should be completed more frequently as the sample approaches SSD condition. Experience with the test and knowledge of the material's characteristics will increase the accuracy of the test.

Vibration of the testing surface leading to a false slump.

Excess airflow near the test sample resulting in uneven drying of the sample.

Loss of material during transfer to the drying pans resulting in an inaccurate calculation.

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Apparatus

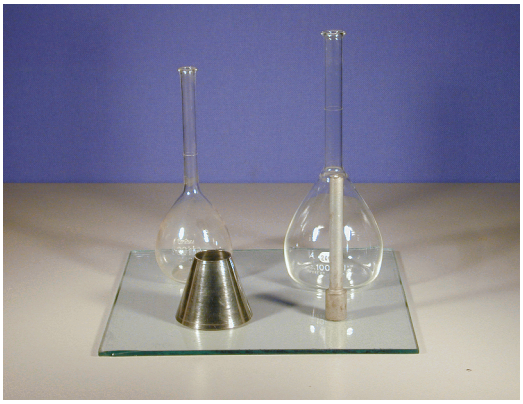
•Balance, conforming to the requirements of M231, Class G2

•Pycnometer: a flask other suitable container into which the fine aggregates can be readily introduced (Figure 1). Volume content for the container needs to be reproduced within ± 100 mm3. The volume of the container filled to the mark shall be at least 50 percent greater than the space required to accommodate the test sample.

•Mold: a metal mold in the form of a frustum of cone with acceptable dimensions as follows: 40±3 mm inside diameter at top, 90±3 mm inside diameter at the bottom, and 75±3 mm in height. The metal thickness is a minimum of 0.8mm.

•Tamper: A metal tamper having a mass of 340±15g and having a flat circular tamping face of 25±3mm in diameter.

Figure 1



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Test Methodology

Step 1. Thoroughly mix the sample and reduce it to sample size in accordance with AASHTO T 248 (Reducing Field Samples of Aggregates to Test Size). The sample size for this procedure is approximately 1 kg of material passing the 4.75 mm (4#) sieve.

Step 2. Dry test sample to constant mass in an oven regulated at 110 ±5°C (230±9°F). Cool the sample at room temperature for 1 to 3 hours. After the cooling period, immerse the sand in water at room temperature for a period of 15 to 19 hours.

In lieu of completely immersing the sand in water, AASHTO considers sand to be "soaked" if it is maintained at a moisture content of at least 6% for the prescribed period. This is the recommended procedure in that it eliminates the need to decant excess water from the sand prior to testing. The decantation process is time consuming and difficult, since great care must be taken to avoid decanting some of the sample along with the water. Additionally, the sand will be much closer to the SSD condition when soaked at 6% moisture, which expedites the drying procedure.

Step 3. Decant water from sample, avoiding loss of fines. Spread sample on a flat, non-absorbent surface. Stir sample occasionally to assist in homogeneous drying. A current of warm air may be used to assist drying procedures (Figure 2).

Figure 2
A current of air being used to achieve SSD condition. Be cautious not to lose fine particles.

Step 4. Determine the SSD condition of the sand using the Cone Test

Figure 3
Tamping sand using the cone method to determine SSD

Special Note: Throughout the process of drying in Step 3, test the sand for SSD condition using the cone method,. Place the cone with the large diameter down on a glass plate. Fill cone to overflowing with drying sand. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper (Figure 3). Each drop should start about 5mm above the top surface of the fine aggregate. Remove loose sand from base and carefully lift the mold vertically. If surface moisture is still present, the fine aggregate will retain its molded shape. When the sand achieves an SSD condition, it will slump (Figure 4).

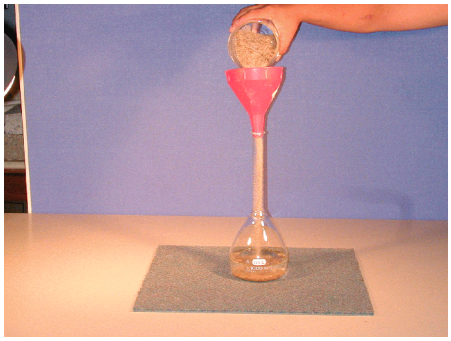
If, on the first trial, the sand slumps, moisture must be re-added and the drying process repeated. Record the mass of the sand as SSD mass when it slumps to the nearest 0.1g..

Figure 4
Sand at SSD condition will slump once the cone is removed

Step 5. Calibrate a specific gravity flask pycnometer by filling with water at 23±1.7°C (73.4±3°F) to calibration line. Record this mass as the mass of the pycnometer filled with water to the nearest 0.1g.

Step 6. Place the SSD sand into the pycnometer (Figure 5) and fill with water (regulated at 23±1.7°C (73.4 ± 3°F) to 90% of pycnometer capacity.

Figure 5
Pouring sand into pycnometer once SSD is achieved



Roll, invert, and agitate the pycnometer to eliminate air bubbles (Figure 6). This procedure should be repeated several times in order to ensure that any entrapped air is eliminated. This process usually takes half an hour total. Agitation of pycnometer does not have to constant.

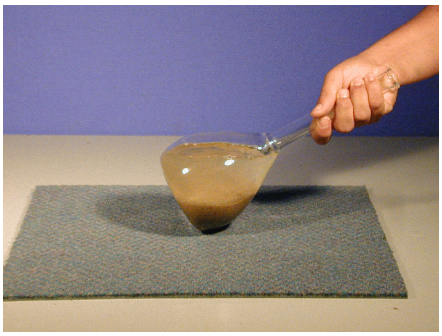
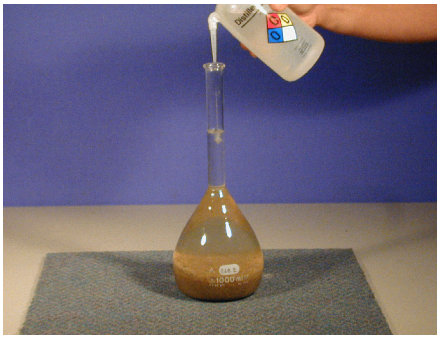


Figure 6

Step 7. Bring the pycnometer to its calibrated capacity with additional water (Figure 7).

Figure 7



If bubbles prevent the proper filling of the pycnometer, adding a few drops of isopropyl alcohol is recommended to disperse the foam. Place the pycnometer in a water bath at the regulated temperature and allow the sample to equalize.

Step 8. Determine the total mass of pycnometer, specimen, and water. Record the mass to the nearest 0.1g as Mass of Pycnometer with sample and water.

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Calculations:

Determine calculations based on appropriate formula for desired result - those formulas are again:

A. Bulk specific Gravity (Gsb): The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at a stated temperature.

$Gsb = A / (B - C)$

Where: A = Oven dry Wt. B = SSD wt. C = Wt. In water

B. Bulk SSD Specific Gravity (Gsb SSD): The ratio of the mass in air of a unit volume of aggregate, INCLUDING the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the mass in air of an equal volume of gas-free distilled water at a stated temperature.

$Gsb\ SSD = B / (B - C)$

C. Apparent Specific Gravity (Gsa): The ratio of the mass in air of a unit volume of the IMPERMEABLE portion of aggregate (does not include the permeable pores in aggregate) to the mass in air of an equal volume of gas-free distilled water at a stated temperature

$Gsa = A / (A - C)$

D. Absorption (%Abs): The increase in mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles.

$\%Abs = [(B - A) / A] \times 100$

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Example Calculations for Fine Aggregate

Trial #	Wet Weight	Dry Weight	Wet – Dry	% Absorbed
1	118.11	117.42	0.69	0.59
2	158.10	157.13	0.97	0.62
3	172.81	171.12	1.09	0.64

Trial	S	A	B	C	B + S – C	B + A – C
1	500.05	497.1	670.7	983.8	186.9	184.0
2	499.77	496.7	679.6	992.4	187.0	183.9
3	499.61	496.5	671.6	984.1	187.1	184.0

Trial	Bulk SSD S/B+S-C	Bulk A/B+S-C	APPARENT A/B+A-C
1	2.675	2.660	2.702
2	2.673	2.656	2.701
3	2.670	2.654	2.698
Average	2.673	2.657	2.700

A = Weight of Oven Dry Specimen in Air
B = Weight of Pycnometer filled with water
C = Weight of Pycnometer with specimen and water to calibration mark
S = SSD Weight

Quiz

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Specific Gravity & Absorption of Fine Aggregates

True or False.

1. When performing a specific gravity test on sand, determine the SSD condition prior to all other determinations.

2. Stirring the sand sample and assisting drying with a fan is permissible in achieving an SSD state.

3. When performing the cone test to check the condition of the sand, use adequate force to drive the tamper and compact the sand as thoroughly as possible.

4. The sand is at an SSD condition when it immediately falls away and retains none of its molded shape whatsoever.

5. After placing the sand in the flask pycnometer, roll and invert it vigorously until all the entrapped air has been evacuated from the sample.

6. Determine the mass of the pycnometer and sample with water as soon as it is filled to the calibration mark.

Calculation Exercise

Complete the following forms by finishing the calculations.

Specific Gravity of Fine Aggregate

Trial #	Wet Weight	Dry Weight	Wet – Dry	% Absorbed
1	154.1	150.0		
2	141.6	138.0		
3	118.1	115.2		

Trial	S	A	B	C	B + S-C	B + A – C
1	503.3		671.2	981.8		
2	503.6		680.2	990.3		
3	513.7		672.0	990.5		
Ave.						

Trial	Bulk SSD S/B+S-C	Bulk A/B+S-C	Apparent A/B+A-C
1			
2			
3			
Ave.			

A = Weight of Oven dry Specimen in Air
B = Weight of Pycnometer filled with water
C = Weight of Pycnometer with specimen and water to calibration mark
S = SSD Weight

Glossary

Absorption: The increase in mass due to water in the pores of the material.

Bulk Specific Gravity (also known as Bulk Dry Specific Gravity): The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

Bulk SSD Specific Gravity: The ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours, to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

Apparent Specific Gravity: The ratio of the mass in air of a unit volume of the impermeable portion of aggregate (does not include the permeable pores in aggregate) to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

SSD – Saturated, Surface Dry. The condition in which the aggregate has been soaked in water and has absorbed water into its pore spaces. The excess, free surface moisture has been removed so that the particles are still saturated, but the surface of the particle is essentially dry.

UNIT WEIGHT AND VOIDS IN AGGREGATE

AASHTO T 19

Developed by
FHWA Multi-regional Aggregate & Certification Group

July, 1999

TABLE OF CONTENTS

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

AASHTO T 19-93 is identical To ASTM C 29-91a.

Reference AASHTO Tests

- AASHTO T 2, Sampling Aggregates
- AASHTO T 84, Specific Gravity and Absorption of Fine Aggregate
- AASHTO T 85, Specific Gravity and Absorption of Coarse Aggregate
- AASHTO T 248, Reducing Field Samples of Aggregates to Testing Size

Reference to ASTM Test

- ASTM D 3665, Practice for Random Sampling of Construction Materials

UNIT WEIGHT AND VOIDS IN AGGREGATE

This test procedure is used to determine the unit weight (mass) of oven dried aggregates, in a calibrated measure, that are in a compacted or loose condition. After the unit weight (mass) has been determined, the void content, space between the aggregate (rock) particles, in that calibrated measure can be calculated. The main reason for determining the void content is to establish accurate material proportions for designing concrete mixes. A minor reason is to determine mass/volume values of products for purchase agreements.

SUMMARY OF TESTING

TEST SAMPLE

- **Representative bulk material/materials should be sampled and reduced to the appropriate sample size by AASHTO specifications.**
- **Sample size should be 125 – 200% more than the capacity of your calibrated container.**
- **If the material to be tested is a combination of 2 or more sizes of material, a composite gradation should be calculated from a minimum of ten field gradations of each separate material. From the composite gradation a test sample should be manufactured.**
- **The test sample shall be dried to a constant weight (mass) in an oven at 110º ± 5ºC (230° ± 9°F).**

TESTING PROCEDURE – RODDING/JIGGING

- **Test procedure is normally determined by the largest nominal size of aggregate to be tested.**
  Rodding – Nominal 37.5 mm (1½ in.) or less.
  Jigging – Nominal 37.5 mm (1½ in.) to 150 mm (6 in.).

¨ ***See 'Ring & Cone' method – page 5*. Dump the prepared sample onto a level, clean, smooth, dry surface (concrete floor) and thoroughly mix by shoveling the sample into a miniature stockpile 3 separate times (A&B). Make each new stockpile by piling one shovel full of material on top of the last in order to form the sample into a stockpile. After the third time spread the material into a uniform circle using a rake for the coarse aggregate (rock) particles and a broom for the fine particles (C-1 thru C-6). Using a flat nosed shovel and counter brush take portions of the sample ring, from the inside to the outside of the ring, first at 180º and then by dividing each section in half (C-7).**

- **Fill the calibrated measure in thirds. After each third, rod or jig as explained below.**

  Rodding – rod each layer with the tamping rod 25 strokes distributed equally over the entire layer surface. On the first layer do not allow the rod to strike the bottom of the measure. On the second and third layers use only enough force for the rod to penetrate the previous layer.

Jigging – jig each layer 50 times, 25 times each side by raising the opposite sides alternately about 50 mm (2 in.) and letting the measure drop in such a manner to sharply hit the base.

The final layer should overflow the top of the measure before and after the rodding/jigging procedure. Then level the surface of the aggregate with a straight edge or by hand in a manner that slight projections of aggregate above the rim balance with the voids below the rim.

- **Determine the mass (weight) of the aggregate and measure.**

- **Follow this procedure a minimum of two times on a given sample as long as the results are within tolerances. Tolerance of one operator is 40kg/m³ (2.5 lb/ft³).**

TESTING PROCEDURE – SHOVELING (Loose Method)

- **Dump the prepared sample into a miniature stockpile on a level, clean, smooth, dry surface (concrete floor). Thoroughly mix the material by reshoveling the sample into a new stockpile 3 times. Make each new stockpile by piling one shovel full of material on top of the last in order to form the sample into a stockpile. After the third time spread the material into a uniform circle by the 'Ring & Cone' method. Using a flat nosed shovel and counter brush take portions of the sample ring, from the outside to the inside of the ring, first at 180º and then by dividing each section in half.**

- **Fill your calibrated measure to overflowing by discharging the aggregate from a height not to exceed 50mm (2 in.).**

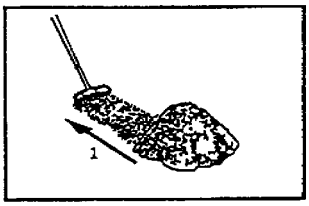
- **Then level the surface of the aggregate with a straight edge, by hand, or rolling a rod in a manner that slight projections of aggregate above the rim balance with the voids below the rim.**

- **Determine the mass (weight) of the aggregate and measure.**

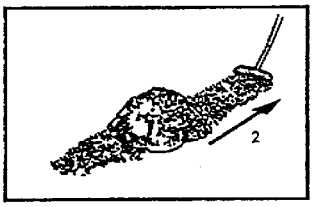
- **Follow this procedure a minimum of two times on a given sample as long as the results are within tolerances. Tolerance of one operator is 40kg/m³ (2.5 lb/ft³).**

RING AND CONE METHOD

A & B



C-1



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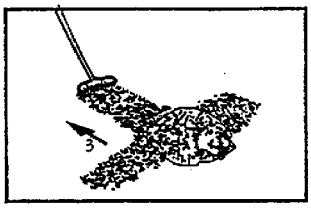

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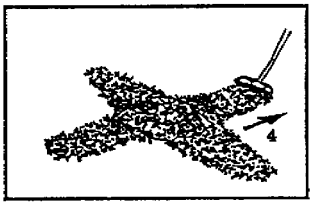
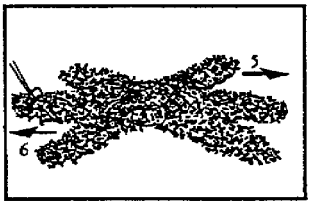


C-3



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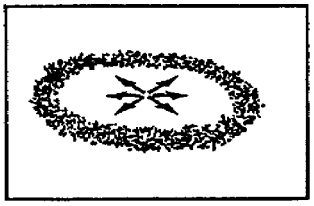

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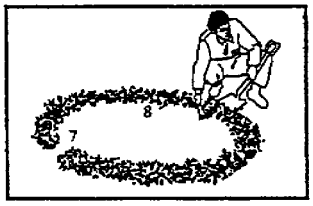
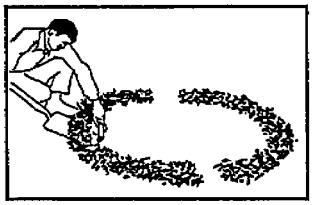


C-7



C-7

CALIBRATION OF THE MEASURE

1. **Determine the mass (weight) of the calibrated measure to the nearest gram.**

2. **Determine the mass (weight) of the calibrated measure with plate glass to the nearest gram.**

3. **Fill the measure with water that is preferably at room temperature, 23.0 °C (73.4 °F), so that the meniscus is above the rim of the measure. Slide the plate glass across the rim of the measure in a way so as to eliminate any air bubbles and excess water. Dry the overflow water off the outside of the measure and plate glass with an absorbent towel. Determine the mass (weight) of the measure, water, and plate glass.**

4. **Measure the temperature of the water to determine its density. See table below.**

TEMPERATURE		KG/M³	LB/FT³
°C	°F		
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
(23.0)	(73.4)	(997.54)	(62.274)
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

5. **Calculate the volume of the measure by dividing the mass of the water required to fill the measure by its density.**

Volume = (Mass of measure, water, and plate glass) – (Mass of measure and plate glass)

Density of the water taken from the above table

Measure Factor = Density of the water ÷ Mass of water to fill measure

EXAMPLE CALIBRATION CALCULATION:

(Measure = 0.014 kg/m³ (1/2 ft³))

Mass of measure, water, and plate glass = 23800 grams
Mass of measure and plate glass = 9350 grams

Water Mass = 14450 grams

Volume = ((14450.0 ÷ 1000 g/kg) ÷ 997.54 kg/m³) = .014 m³
Measure Factor = (997.54 kg/m³ ÷ 14.45 kg) = 69.034

EQUIPMENT

Balance (Scale) — **The balance will have sufficient capacity to determine the mass (weight) of the sample and calibrated measure to the nearest gram.**

Tamping Rod — **A round, straight steel rod 16 mm (5/8 in.) in diameter and a minimum 600 mm (24 in.) in length, having one end rounded to a hemispherical tip of the same diameter as the rod, and preferably with an oversized handle at the other end.**

Measure — **A cylindrical metal measure with handles on the sides; top and bottom level to within 0.5 degree of each other; plum and smooth inside surface with height within 80-150% of the diameter. Capacity of the measure will be determined by the nominal size of the aggregate to be tested. The top rim will be smooth and true so that a .25 mm (0.01 in.) feeler gauge cannot be inserted between the rim of the measure and a piece of plate glass that is a minimum of 6 mm (1/4 in.) thick and at least 25 mm (1 in.) larger than the diameter of your calibrated measure. See tables below.**

Miscellaneous — **Square nosed shovel, flat metal dustpan or scoop, rake, counter brush and broom.**

CAPACITY OF MEASURES

Nominal Maximum Size of Aggregate		Capacity of the Measure	
mm	In.	L(m^3)	ft^3
12.5	½	2.8 (0.0028)	1/10
25.0	1	9.3 (0.0093)	1/3
37.5	1 ½	14 (0.014)	½
75	3	28 (0.028)	1
112	4 ½	70 (0.070)	2 ½
150	6	100 (0.100)	3 ½

REQUIREMENTS FOR MEASURES

Capacity of Measure	Thickness of Metal, min		
	Bottom	Upper 1 ½ in. Or 38 mm of Wall[A]	Remainder of Wall
Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
0.4 ft^3 to 1.5 ft^3 , incl	0.20 in.	0.20 in.	0.12 in
Over 1.5 to 2.8 ft^3, incl	0.40 in.	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft^3, incl	0.50 in.	0.30 in.	0.20 in.
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm

[A]The added thickness in the upper portion of the wall may be accomplished by placing a reinforcing band around the top of the measure.

COMMON TESTING ERRORS

- **Loss of sample material during test**
- **Leveling top layer inconsistently**
- **Sample not oven dried**
- **Rodding too hard**

ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE (COLOR PLATE TEST)

AASHTO T 21

Developed by
FHWA Multi-regional Aggregate & Certification Group
1999

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NOTE:

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO is identical to ASTM C 40-84

Reference AASHTO Tests

- AASHTO M 6, Fine Aggregate For Portland Cement
- AASHTO T 2, Sampling Aggregates
- AASHTO T 71, Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
- AASHTO T 248, Reducing Field Samples of Aggregates to Testing Size

GLOSSARY

Standard Color Solution	-	DO NOT USE THIS SOLUTION IF AN ALTERNATIVE METHOD IS AVAILABLE. This is a reagent grade potassium dichromate in a concentrated sulfuric acid solution that must be mixed by a qualified chemist and be prepared to use all required safety equipment and procedures.
Gardner Color Standard	-	Refer to ASTM D 1544, Table 1.
Organic Plate	-	Refer to ASTM D 1544, Table 1.
Air Dried Sample	-	Sample of the material to be tested that is allowed to dry naturally, **not oven dried.**
Fine Aggregate (Sand)	-	Material that is generally used in concrete mixes.

ORGANIC IMPURITIES IN FINE AGGREGATES FOR CONCRETE

This test procedure is used to determine if there is a possible presence of harmful organic material in the fine aggregate (sand) that is to be used in cement mortars or concrete mixes. New fine aggregate (sand) sources should be tested for organic material before using this sand in cement mortars or concrete mixes.

If test results show the presence of organic materials in a representative fine aggregate (sand) sample, it is advisable to run strength tests on this material. The strength test will determine if the organic material will be harmful to the cement mortar or concrete mixes. The costs and time used to thoroughly test this fine aggregate (sand) source are minimal compared to possible major repair or replacement costs.

SUMMARY OF TESTING

To determine if a fine aggregate (sand) source is contaminated with organic material, prepare a representative sample of 1350 grams (3 lbs.) and allow it to air dry. Take a clear glass oval or rectangular bottle that has a stopper or cap and is graduated in milliliters (mL) or ounces (oz). Determine and mark on the bottle the graduated levels of 130 mL (4½ oz.) and 200 mL (7 oz.). Prepare a 3% sodium hydroxide (NaOH) solution. (3 parts sodium hydroxide with 97 parts water) Using a small funnel, pour the air-dried sample material into the bottle until it is level with the 130 mL (4½ oz.) mark. Then add 3% sodium hydroxide (NaOH) solution until the volume of the sample and solution, after gently shaking, is at the 200 mL (7 oz.) mark. Now stopper or cap the bottle and shake vigorously and then allow to stand for 24 hours. After 24 hours compare the color of the solution in the bottle above the sample with one of the following:

1. Gardner Color Standard No. 11.
2. Organic Plate No. 3.
3. 75 mL (2½ oz.) of Standard Color solution prepared no longer than 2 hours previously.

If the solution in the test sample bottle is darker than the standard used for this test procedure, the fine aggregate should be tested further before approving for use in any concrete mortars or mixes.

COMMON TESTING ERRORS

- Oven drying the sample material.
- Incorrect proportioning of sodium hydroxide (NaOH) solution

EQUIPMENT

- Clear glass bottle graduated in milliliters (mL) or ounces (oz) with a cross section that is approximately oval and measures between 40-60 mm (1½ - 2½ in.) across the line of sight that will be used to compare the color of the solutions.
- Water tight stopper or cap.
- 3% sodium hydroxide (NaOH) solution.
- Gardner Color Standard No. 11, Organic Plate No. 3, or Reference color solution.

LIGHTWEIGHT PIECES IN AGGREGATE

AASHTO T 113

Developed by
FHWA Multi-Regional Aggregates Training & Certification Group
1999

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NOTE

Successful completions of the following training material, including examination and performance evaluation are prerequisites for this training package.

- ♦ AASHTO T 84, Specific Gravity of Fine Aggregates.
- ♦ AASHTO T 85, Specific Gravity of Coarse Aggregates.
- ♦ AASHTO T 248, Reducing Samples Of Aggregate To Testing Size.

LIGHTWEIGHT PIECES IN AGGREGATE

This test method determines the percentage of lightweight particles in aggregate by means of sink/float separation using heavy media solutions. The particles with a specific gravity less than the solution in which they are immersed will float to the surface where they can be skimmed off and weighed. The weight of the lightweight particles divided by the weight of original sample determines the percent of lightweight particles.

The percent of lightweight particles is of particular importance when the aggregate is intended for use in Portland Cement Concrete (PCC). Some mineral aggregates, for example chert, have low specific gravities and can work their way to the surface of a PCC pavement during finishing. Chert tends to fracture during freeze-thaw conditions and causes pop-outs or hollow indentations in the concrete surface.

SUMMARY OF TESTING

WARNING !!!

THIS TEST PROCEDURE INVOLVES HAZARDOUS CHEMICALS. EXTREME CAUTION IS REQUIRED!

Read safety warning statements in AASHTO T 113, as well as, MSDS (Material /Safety Data Sheets) for chemicals used, prior to initiating testing.

This test must be performed by a certified/qualified technician or chemist. There is a specific guideline of precautions that need to be taken with each chemical used. It is very important to be familiar with each of these precautions before performing this test.

Samples

Secure a field sample and oven dry to a constant weight. Reduce the test specimens according to AASHTO T 248 and the following chart:

Nominal Maximum Size of Aggregate (Square Opening Sieves)	Minimum Wgt. of Sample, grams
4.75 mm (No. 4)	200
19.0 mm (¾ in.)	3,000
37.5 mm (1½ in)	5,000
75.0 mm (3 in.)	10,000

Normally, a solution of chemicals at a specific gravity of 2.40 is used for separation of lightweight materials in coarse aggregate. A solution of chemicals at a specific gravity of 2.00 is used for separation of fine aggregate lightweight particles, in particular coal and lignite.

Heavy Media shall be one of the following:

- Zinc chloride in water (Specific Gravity up to 2.0).
- A solution of Zinc Bromide in water (Specific Gravity up to 2.40).
- A mixture of kerosene and 1,1,2,2 Tetrabromoethane proportioned to produce the desired specific gravity (1,1,2,2 Tetrabromoethane has a specific gravity of 2.95).

Note: *Set the specific gravity of the solution to coincide with the specifications of your state.*

Periodically check the specific gravity of the solution.

TEST METHODOLOGY

Apparatus

Beaker (500 mL)
Vented Oven
Sieves and sieve cloth
Safety clothing and equipment

Fine Aggregate

Sieve dried material over a 300 μm (No. 50) sieve. Weigh the sample to the nearest 0.1 gram.

Immerse the test sample in water for 24 hours. Bring the specimen to a saturated surface dry condition (in accordance with AASHTO T 84). Carefully pour the test sample into a suitable container (a 500 mL beaker is sufficient) containing the appropriate heavy media solution. For fine aggregate a specific gravity of 2.00 is used for the coal and lignite particles. The liquid should be at least three times the volume of the sample.

Place a 300 μm (No. 50) sieve cloth over an empty beaker. This will be used as a skimmer. Pour floating particles over the skimmer. Agitate, by stirring, the remaining liquid and sample to release any lightweight particles that may have been trapped. Repeat the skimming process.

Wash the lightweight pieces in an appropriate solvent to remove the heavy liquid. Alcohol for 1,1,2,2 tetrabromoethane, water for zinc chloride and zinc bromide.

Dry the lightweight pieces to a constant weight, in a vented oven. Weigh to the nearest 0.1 gram.

Coarse Aggregate

Sieve the oven dried sample over a 4.75 mm (No. 4) sieve to obtain the appropriate test specimen. Weigh the sample to the nearest 0.1 g and submerse it in water for 24 hours.

Bring the specimen to a saturated surface dry condition (in accordance to AASHTO T 85). Gradually begin to introduce the specimen to the appropriate heavy media. For coarse aggregate, a specific gravity of 2.40 is used to determine lightweight pieces.

As pieces float to the surface, skim them off and agitate, by stirring, the liquid to free up other lightweight pieces.

Rinse all the lightweight pieces in the appropriate solvent. This would include, alcohol for 1,1,2,2 tetrabromoethane, water for zinc chloride, and zinc bromide.

Dry lightweight pieces to a constant weight in a vented oven. Weigh to the nearest 0.1 g.

Calculation

Calculate the percentage of lightweight pieces as follows:

Fine Aggregate	$L = (W1/W2) \times 100$
Coarse Aggregate	$L = (W1/W3) \times 100$

L = percentage of lightweight pieces
W1 = dry weight of lightweight pieces
W2 = original weight of coarser than No. 50 sieve material (fine aggregate)
W3 = original weight of coarser than 4.75 mm (No.4) sieve material (coarse aggregate)

SODIUM SULFATE SOUNDNESS

AASHTO T 104

Developed by
FHWA Multi-Regional Aggregates Training & Certification Group

July, 1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T11, Materials Finer than 75µm (No. 200) Sieve by Washing.
- AASHTO T27, Sieve Analysis of Coarse and Fine Aggregate

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AASHTO T 104 Sodium Sulfate Soundness

Scope

Aggregate samples are subjected to alternate cycles of immersion in soundness solution (sodium or magnesium sulfate) and drying in an oven at a regulated temperature of 110±5°C (230±9°F). Salts penetrate the permeable void space of the aggregates during the soaking phase (16–18 hrs.). During the drying phase the salt dehydrates (Figure 1). Upon re-immersion, the salt re-hydrates creating an internal expansive force simulating the expansion that occurs when water freezes. This pressure simulates the expansion of water when frozen. Soundness testing helps engineers to judge the degradation susceptibility of aggregates when subjected to weathering. Soundness testing values are used when there is inadequate information regarding the actual weathering of aggregates in use. Soundness values are expressed as a weighted average percentage of loss for each aggregate size, based on the original sample grading determined by AASHTO T27.

Note:
It is the re-hydration, not the dehydration process that creates the expansive force.

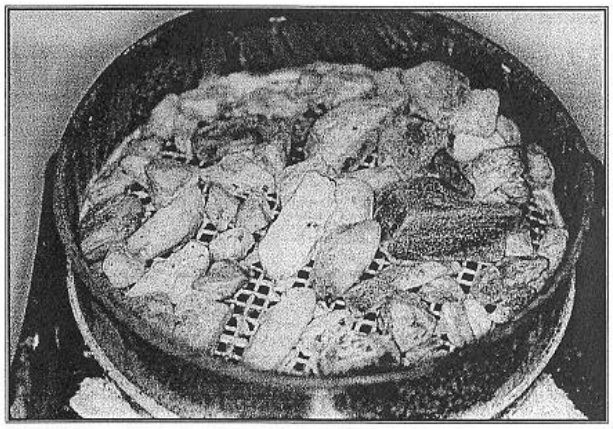

Figure 1- Salt on aggregate particles

Instructor's Note:
The AASHTO T 27 gradation will be used to tell you what individual fraction samples must be prepared to run the soundness test and how much material you will need for each fraction.

Common Testing Errors

- Improper temperature of salt solution.
- Improper solution concentration (Specific Gravity)
- Insufficient drying times. (See Section 7.2 in AASHTO T 104)
- Incomplete removal of salt by washing at completion of testing. (see section 8.11 in AASHTO T104 for details on assuring complete salt removal)
- Excessive agitation of coarse aggregate during post-test sieving. Agitation should be minimized in order to remove undersized particles, while not causing further breakdown of particles that were not degraded during actual testing.
- Prevent loss of material during testing procedure.

Apparatus

- Balance
- Sieves: Conforming to AASHTO M92 for sieving samples.
- Sample Containers: Sieves 203.2 mm (8”) in diameter for separate size fractions of aggregate during test.

> **Instructor’s Note:**
> Sieves out of tolerance with AASHTO M 92, in an acceptable condition, may be used as sample containers. For coarse aggregates, 2.36 mm (#8) sieve. For fine aggregates, 0.250 mm (#60).

- Apparatus for immersing samples in solution: Optional, for permitting free access of solution to sample and to provide for free drainage of solution.
- Temperature regulation: Suitable means for providing temperature regulation 20.3° to 21.9°C (68.5 to 71.5°F) of the samples during immersion is required.
- Drying Oven: Must be capable of maintaining heat level of 110±5°C (230±9°F) for drying phase. Oven must also be capable of maintaining an evaporation rate of 25 grams per hour over a four hour period (see “Determining Evaporation Rate, following page).
- Hydrometers capable of measuring specific gravities between 1.297 and 1.306, as well as, 1.154 and 1.171, within ± 0.001 and conforming to ASTM E 100.

- In lieu of hydrometers, AASHTO T104 allows the use of graduated glassware and a scale to determine the specific gravity (G) of the solution.
- Prepared Soundness Solution.
  - Magnesium sulfate or sodium sulfate, depending upon the procedure being used.
  - Barium Chloride Solution.
    - 0.2 molar solution of barium chloride to determine the presence of magnesium or sodium sulfate in the wash water for the rinsing portion of the test.

Determining Evaporation Rate

1. Prepare five 1 liter Griffin low–form beakers for each shelf of the oven. Beakers will be placed in the center and at each corner of each shelf in the oven (Figure 2).

2. Place 500 grams of water in each beaker at 21±2°C(70±3°F). Place beakers on shelves in oven regulated at 110±5°C (230±9°F) for 4 hours. Do not open the oven doors during the evaporation test. Make sure oven vents are open to allow for venting of evaporate moisture.
3. At the end of the four hour period, remove beakers, cool to room temperature and record mass of water remaining in each beaker. The water mass in each beaker must be no more than 400 grams as per the 25 gram per hour required evaporation rate. That is, each beaker must lose at least 100 grams of water after 4 hours in an oven regulated at 110±5°C (230±9°F).

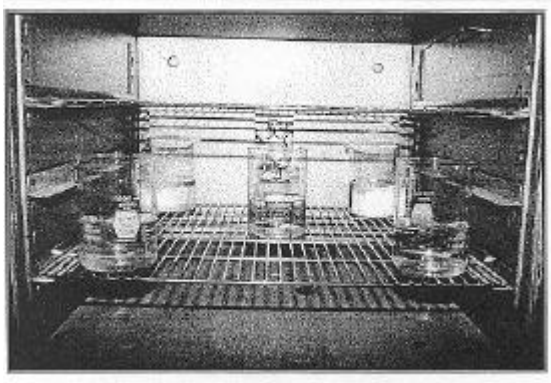

Figure 2 - Low form beakers on oven shelf

Solution Preparation

1. Solution needs to be prepared at least 48 hours in advance of the test procedure. Enough

solution should be prepared to be at least 5 times the solid volume of all the samples to be tested.

2. Prepare a saturated solution of either sodium sulfate (Na2SO4) or magnesium sulfate (MgSO4) using a reagent grade of salts added to distilled water. Distilled water is not required but shall be used in referee or comparison testing.

3. Add enough salt to the water to ensure not only saturation but the presence of excess crystals when the solution is ready for use in the tests. This can be accomplished by continually adding salts to the water and stirring. Add salts in increments allowing it to dissolve to determine crystallization potential.

NOTE:

For the sodium sulfate solution 225 grams per liter of solution is recommended to achieve the saturated state. For magnesium sulfate solution, 350 grams of anhydrous salt per liter of solution is recommended. When using heptahydrate salt, (commonly known as Epsom Salt), 1400 grams per liter of solution is recommended to achieve the saturated state.

4. Cover solution container while not in use to prevent evaporation and contamination. Allow the solution to cool to 20.3° to 21.9°C (68.5 to 71.5°F).

Instructor's Note: - Parafilm, Cellophane or Plexiglass may be used as a cover.

5. Stir the solution and allow it to stand at least 48 hrs. Before use, break up the salt cakes, if any, prior to submerging the samples into the solution.

6. Check and record specific gravity and temperature of the solution each day the test is run. **The temperature requirement for both solutions is 20.3 to 21.9°C (68.5 to 71.5°F). The magnesium sulfate specific gravity is required to be maintained between 1.297 and 1.306. The sodium sulfate specific gravity is required to be maintained between 1.154 and 1.171.**

Sample Sizes

Fine Aggregate

Sample should be passed through a 9.5 mm (3/8") sieve. The sample must be large enough to yield not less than 100 grams for each of the following, sieves as listed in Table 1. If the sample being tested contains less than 5% of any of the following sizes listed in Table 1, that size shall not be tested. Therefore, a 100 g sample of the fraction that is less than 5% of the total will not have to be prepared.

Passing Sieve	Retained on Sieve
9.5 mm (3/8")	4.75 mm (#4)
4.75 mm (#4)	2.36 mm (#8)
2.36 mm (#8)	1.18 mm (#16)
1.18 mm (#16)	0.600 mm (#30)
0.600 mm (#30)	0.300 mm (#50)

Table 1 - Sieve fractions which compose grading of soundness sample.

Coarse Aggregate

Remove all particles passing the 4.75 mm (#4) prior to test. The sample should be of such a size as to conform to the mass requirements in Table 2.

Sieve Size, mm (in.)	Mass, g
63 to 37.5 (2½ to 1½) consisting of:	5000±300
50 to 37.5 (2 to 1½)	2000±200
63 to 50 (2½ to 2)	3000±300
37.5 to 19.0 (1 to ¾) consisting of:	1500±50
25 to 19 (1 to ¾)	500±30
37.5 to 25 (1½ to 1)	1000±50
19 to 12.5 (¾ to d) consisting of:	1000±10
19 to 12.5 (¾ to ½)	670±10
12.5 to 9.5 (½ to d)	330±5
9.5 to 4.75 (d to #4)	300±5

Table 2 - Mass of separate size fraction of coarse aggregate to be used for soundness sample.

Special considerations for sample preparation

1. If the sample should contain less than 5% of any of the prescribed sieve sizes, the size should not be tested. When a combination of sizes is specified and one of the sizes specified is less than 5%, reduce the test portion by the applicable mass as listed in the table.

2. When testing large rock, obtain the test portion by crushing, splitting, or sawing the larger pieces. Test only those pieces in the 37.5 to 19.0 mm (1 ½" to ¾") and 63 to 37.5 mm (2 ½" to 1 ½") size fractions when reduction is by crushing or splitting. Test 63 to 37.5 mm (2 ½" to 1 ½") size fractions when reduction is by sawing.

3. When testing large rock which will be crushed, obtain the test portion by crushing the aggregate. Test pieces only in those sizes which will be included in the test aggregate, but ignoring any material finer than the 4.75 mm (#4) sieve or larger than the 63 mm (2 ½").

4. When the finished aggregate will contain pieces larger than 63 mm (2 ½"), crush the pieces larger than the 63 mm (2 ½") and distribute the material among the range of 63 mm (2 1/2") to 4.75 mm (#4) sieves.

5. When an aggregate being tested contains appreciable amounts of both fine and coarse material, having a grading with more than 10% coarser than the 9.5 mm (d") sieve, and more than 10% finer than the 4.75 mm (#4) sieve, test separate samples of the coarse and fine particles in accordance with the procedures for the coarse and fine aggregate particles, respectively. Report the results separately for the fine and coarse aggregate portion of the test, giving the percentages of fine and coarse aggregates in the original grading.

Sample Preparation

Fine Aggregate

1. Thoroughly wash the sample of fine aggregate on a 300 micron (#50) sieve, and dry to a constant mass at 110±5°C (230±9°F).

2. Separate the dried sample into the different sizes by sieving as required. Make a rough separation of the sample using the appropriate sieves. Obtain enough material to yield at least 100 grams of material on each sieve.

3. Sieve the rough–cut sample to refusal. Sieving to refusal means that no more material will pass through the sieves after additional agitation.

4. Weigh out the samples consisting of 100±0.1 grams out of each of the separated fractions after final sieving. Record the mass of the test samples and place in separate containers for the test.

Coarse Aggregate

1. Thoroughly wash and dry the sample of coarse aggregate to a constant mass at 110±5°C (230±9°F).

2. Separate the sample into the different sizes within the tolerances as described earlier by sieving until no more material will pass through the sieve after additional sieving. Record the mass of the test samples and combine them to the designated total mass.

3. In the case of particles larger than 19.0 mm (3/4”), record the number of particles in the test sample.

Procedure

1. Immerse the samples in the prepared solution 16 to 18 hours (Figure 3). The solution should cover the samples to a depth of at least 12.5 mm (1/2”). Cover the soundness tanks to reduce evaporation and contamination. Maintain the samples immersed in the solution at 20.3 to 21.9°C (68.5 to 71.5°F).

2. After the soaking period, remove the sample from the solution and allow it to drain for 15±5 minutes.

3. After draining, place the sample in an oven regulated at 110±5°C (230±9°F). Dry the samples until a constant mass has been obtained.

Determination of Constant Mass

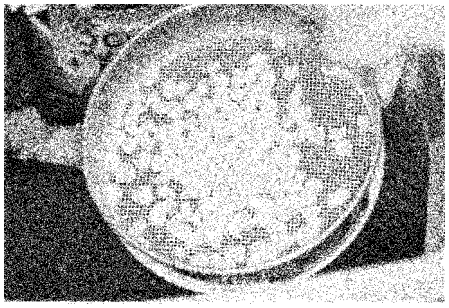

Figure 3 - Placing sample back into tanks for another cycle.

1. With the oven containing the maximum sample load expected, check the mass losses of test samples by removing them and weighing without cooling, at intervals of 2 to 4 hours.

2. Make enough measurements to determine the drying time for the least favorable oven location and sample condition.

3. Constant mass is determined when mass loss is less than 0.1% of sample mass in 4 hours of drying.

4. After constant mass has been obtained, allow the sample to cool to 20° to 25°C (68° to 77°F), when they shall again be immersed in the prepared solution. Cooling may be aided by the use of an air conditioner or fan. Temperature of the material should be checked prior to immersion in the soaking solution.

5. Repeat the process of immersion and drying until the required number of cycles has been

completed. The test should be performed continuously until all cycles are completed. If the test must be interrupted, leave the samples in the oven at 110±5°C (230±9°F) until testing can be resumed.

6. Once all cycles have been completed, and the sample is cooled, wash the sample free from the salt solution by circulating water at 43°±6°C (110±10°F) through the samples and their containers by introducing hot water near the bottom and allowing it to pass through the samples and overflow (Figure 4).

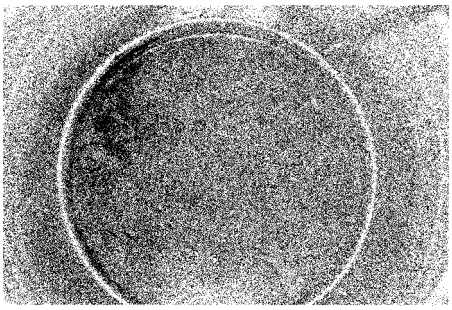

Figure 4 - Rinsing aggregate free of solution after last cycle.

7. Check washing thoroughness by obtaining a sample of the rinse water after it has overflowed the samples and check with 0.2 molar barium chloride. Further washing is needed if the barium chloride causes the water to become cloudy. If tap water gives a reaction with barium chloride, other analytical means should be used.

8. After the solution has been completely removed from the aggregate samples, dry each fraction of the sample to a constant mass at 110±5°C (230±9°F).

9. Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the specified sieves for the appropriate size of the particles (Table 3).

10. Sieve fine aggregate using the same mechanism and duration used for the original sample preparation.

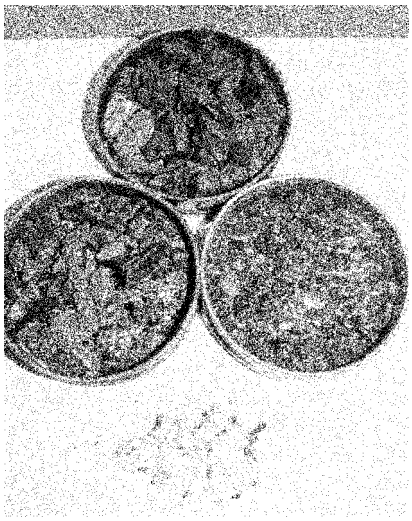

Figure 5 - Appearance of aggregate after it has been rinsed free of solution, prior to final shake. Note flaky debris near bottom of picture.

11. Sieve coarse aggregate by hand, with agitation sufficient only to assure that all undersized material passes the designated sieve. No extra manipulation should be employed to break up particles.

12. Determine the mass of the particles retained on each sieve and record each amount. The difference between each of the amounts and the initial mass of the fraction of the sample tested is the loss and is to be expressed as a percentage of the original mass.

13. Perform the qualitative examination of aggregate particles larger than 19.0 mm (3/4”) and record the number of particles showing each of the following types of distress: disintegration, splitting, crumbling, cracking, flaking, etc (Figure 5).

14. Report the following data: Mass of original sample on sieve fractions, mass of sample on prescribed - “backsieves” after cycles are completed, the loss of

material as expressed as a percentage of the original sample fraction mass, and the weighted average calculated from the percentage of loss for each fraction, based on the original grading of the sample.

Size Fraction	Screen used to determine loss
63mm - 37.5mm (2-1/2" - 1-1/2")	31.5mm (1-1/4")
37.5mm - 19.0m (1-1/2" - 3/4")	16.0mm (5/8")
19.0mm - 9.5mm (3/4" - 3/8")	8.0mm (5/16")
9.5mm - 4.75mm (3/8" - #4)	4.0mm (#5)
Fine Aggregates	Same sieve used in set up

Table 3. Sieves for re-sieving aggregate after soundness testing for quantitative examination.

Example Calculation

Sieve Size	Original mass	Final mass	Loss in mass	%Loss	Original Grading	Wtd. Loss
25 mm to 19 mm (1" to ¾")	515.3	462.1	53.2	10.3	73.2	7.5
19 mm to 12.5 mm (¾" to ½")	668.7	501.2	167.5	25	18.9	4.7
12.5 mm to 9.5 mm (½" to d")	334.2	261.3	72.9	21.8	5.7	1.2
						Total Wtd. Average=13

GLOSSARY

Soundness - Durability or resistance to weathering.

Permeable - The capacity of an aggregate particle or group of particles to transmit fluid.

Degradation/Weathering- Breakdown of aggregate when subjected to applied forces or weathering events such as freeze-thaw.

DETERMINING PERCENT OF FRACTURED PARTICLES IN COARSE AGGREGATE

ASTM D 5821

Developed by
FHWA Multi-regional Aggregate Training & Certification Group

July, 1999

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NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

Reference ASTM Standard Tests

- ASTM C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregate
- ASTM C 702 Practice of Reducing Field Samples of Aggregate to Test Size
- ASTM D 75 Practice of Sampling Aggregate

Reference AASHTO Tests to ASTM Standard Tests Listed Above

- AASHTO T 2 is identical to ASTM D 75
- AASHTO T 248 is identical to ASTM C 702
- AASHTO T 27 does differ slightly with ASTM C 136

SCOPE

This test procedure determines the amount (percent) of fracture faced rock particles, by visual inspection that meets specific requirements. The fractured face of each rock particle must meet a minimum cross-sectional area (See Terminology). Specifications contain requirements for percentage of crushed rock particles, with the purpose of maximizing shear strength in either bound or unbound aggregate mixtures. This method can be used in determining the acceptability of coarse, dense-graded, and open-graded aggregates with respect to such requirements. This procedure is used primarily for bituminous aggregates.

TERMINOLOGY

Fractured Face - A fractured face is defined as being caused either by mechanical means or by nature and should **have sharp or slightly blunted edges**. Natural fractures, to be accepted, must be similar to fractures produced by a crusher. A broken surface constituting an area equal to at least 25% of the projected area of the particle, as viewed perpendicular to (looking directly at) the fractured face.

Fractured Rock Particle - A rock particle having at least one fractured face, or two fractured faces, as required for that class/type of aggregate in the specifications.

EQUIPMENT

A. Sieves - A set of sieves appropriate for the sample type.

B. Balance - appropriate for the size of sample and accurate to 0.1g.

C. Spatula or similar tool to aid in sorting the aggregate particles.

D. Paper Containers.


CRUSHED ROCK
FRACTURED
MATERIAL


NON-FRACTURED
MATERIAL


QUESTIONABLE
QUESTIONABLE


FRACTURED
MATERIAL
*DOES NOT MEET
GUIDELINES

SAMPLE PREPARATION

Air-dry the representative sample prior to the coarse gradation process so that there is a clean separation of the particles. A total + 4.75 mm (No. 4) sample could be set up for testing or more commonly the + 4.75 mm (No. 4) material will be split into representative fractions. It will be necessary to determine the correct proportions between the two fractions and this may be calculated from gradation results. All the material passing and retained on the appropriate sieves for the selected fractions are weighed and the sum of the weights equal the total +4.75 mm (No. 4) material. Then the material from each fraction is split down to the required sample size and tested or any other method that maintains the proportional relationship between the two or more fractions and provides a representative sample for each fraction. ***See table below for *nominal maximum sieve sizes and minimum sample sizes.***

SPLIT SAMPLE AND SINGLE SAMPLE SIZES

SIEVE SIZE	**SIZE SIEVE**	**SAMPLE SIZE PERCENT CRUSHED ONLY**	
mm	**Inch**	**(grams)**	**(lbs)**
9.5 - 4.75 19.0 - 9.5	3/8" - #4 3/4 – 3/8"	450 – 550 1500 – 2000	1 4 – 5
12.5 - 4.75 19.0 - 12.5	1/2" - #4 3/4 – 1/2"	900 – 1100 1500 – 2000	2 – 3 4 – 5
MAXIMUM NOMINAL SIEVE SIZES	**MAXIMUM NOMINAL SIEVE SIZES**	**SAMPLE SIZE PERCENT CRUSHED ONLY**	
mm	**Inch**	**(grams)**	**(lbs)**
9.5	3/8”	450 – 550	1
12.5	1/2"	900 – 1100	2 – 3
19.0	¾”	1500 – 2000	4 – 5
25.0	1”	3000±	6 – 7
37.5	1½”	7500±	16 – 17

**** NOTE: Nominal maximum sieve size is defined as the largest sieve size listed in the applicable specification upon which any material is permitted to be retained.***

TEST PROCEDURE

A. Wash and then dry to a constant mass (weight). Weigh the test sample to the nearest 0.1g and record as "Test Sample Weight".

B. Spread the test sample on a clean, flat surface large enough to permit the material to be spread thinly for careful inspection and evaluation.

C. Using the spatula or a similar tool separate the particles into one of the following three categories.

1. **Crushed Particles**, using the criteria of "one or more fractured faces" or "two or more fractured faces" as is consistent with the requirements in the specifications.

2. **Uncrushed Particles**

3. **Questionable Particles,** referring to the criteria listed under Fractured Face (page 4), the rock particle is boarder line in meeting fractured face area or the fractured area is natural and has rounded edges.

D. Determine the mass (weight) of the "Crushed Particles" and "Questionable Particles" separately and record the weights as "Weight of Crushed Particles" and "Weight of Questionable Particles".

NOTE:
The mass (weight) of the Questionable Particles (QP) shall not exceed 20% of the total Test Sample Weight (TSW). If the QP mass (weight) is larger than 20% of the TSW, re-evaluate all the QP making a closer decision concerning crushed/non-crushed, so that the

COMMON TESTING ERRORS

- Sample not representative
- To many questionable particles

CALCULATION

A. Calculate the percentage of crushed particles for each separate fraction as follows:

$$\text{Percent Crushed Particles (}\mathbf{CP}\text{)} = \frac{A + (B \div 2)}{C} \times 100$$

Where: A = Weight of crushed particles with at least the specified number of fractured faces, in grams.

B = Weight of questionable particles, in grams.

C = Weight of the test sample, in grams.

In the example, 19.0 to 9.5 mm (3/4 to 3/8") size:

A = 730
B = 104
C = 1850

$$\mathbf{CP} = \frac{730 + (104 \div 2)}{1850} \times 100 = 42.3\%$$

In the example, 9.5 to 4.75 mm (3/8" – No. 4) size:

A = 350
B = 70
C = 470

$$\mathbf{CP} = \frac{350 + (70 \div 2)}{470} \times 100 = 81.9\%$$

B. Total Percentage of Crushed Particles (**TPC**) Retained on the 4.75mm (No. 4) Sieve.

Determine the percentages of the 19.0 to 9.5 mm (3/4 to 3/8") and the 9.5 to 4.75 mm (3/8" to No. 4) fractions using the material retained on the 4.75 mm (No. 4) sieve as 100%.

Example:

19.0 - 9.5 mm (3/4 - 3/8") Material	**=**	3766g
9.5 - 4.75 mm (3/8 – No. 4) Material	**=**	7314g
Total +4.75 mm (No. 4) Material	**=**	11080g

$$\text{Percent 19.0 - 9.5 mm (3/4 - 3/8")} = \frac{3766}{11080} \times 100 = 34\%$$

$$\text{Percent 9.5 - 4.75 mm (3/8" – No. 4)} = \frac{7314}{11080} \times 100 = 66\%$$

Total Percent Crushed Particles (**TPC**) =

(% Crushed Particles 19.0 - 9.5 mm [3/4 to 3/8"]) **x**
(% of 19.0 - 9.5 mm [3/4 to 3/8"] Material)

+

(% Crushed Particles 9.5 - 4.75 mm [3/8" – No. 4]) **x**
(% of 9.5 - 4.75 mm [3/8" – No. 4] Material)

In the Example:

(0.423 **x** 0.34) **+** (0.819 **x** 0.66) **=**

(0.144) **+** (0.541) **=** 68.5% (**TPC**)

FLAT PARTICLES, ELONGATED PARTICLES, OR FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE

ASTM D 4791

Developed by:

Federal Highway Administration Multi-Regional
Aggregate Training and Certification Group

July, 1999

TABLE OF CONTENT

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- ♦ AASHTO D 75, Practice for Sampling Aggregates.
- ♦ ASTM D 3665, Practice for Random Sampling of Construction Materials
- ♦ AASHTO T 248, Reducing Sample of Aggregate to Testing Size.
- ♦ AASHTO T 27, Sieve Analysis of Aggregates.

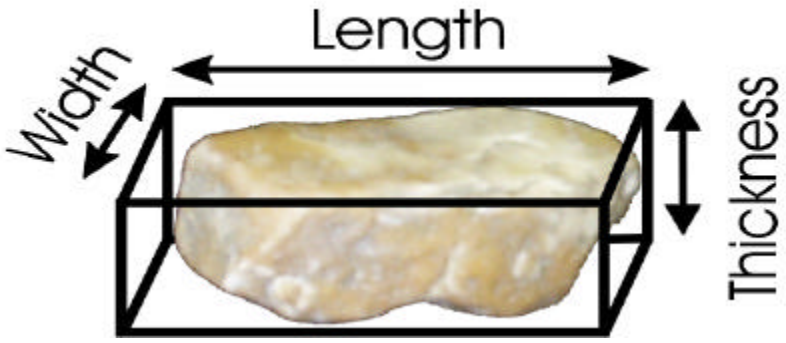
GLOSSARY

Flat and Elongated Particles of Aggregate - Those particles having a ratio of length to thickness greater than a specified value.

Length - the longest dimension.

Thickness - the smallest dimension.

Width - the other dimension**.**



FLAT PARTICLES, ELONGATED PARTICLES, OR FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE

This test method covers tests for flat particles, elongated particles, or flat and elongated particles in coarse aggregate. In this text only flat and elongated particles will be covered because at this time the only national specification that references this test is the Superpave Specification, which refers to Flat and Elongated Particles in Coarse Aggregate.

Flat and elongated particles of coarse aggregates have a tendency to fracture more easily than other aggregate particles. When the coarse aggregate does fracture, the gradation will likely change which may be detrimental to the mix. Additionally, flat and elongated particles of aggregate, for some construction uses, may interfere with consolidation and may result in harsh, difficult to place mixtures.

NOTE
This test method is being reviewed and could be changed in the future.

SUMMARY OF TESTING

Individual aggregates of specific sieve sizes are tested for ratios of width to thickness, length to width, or length to thickness. The test is performed on a sample of coarse aggregate reduced from a representative field sample. The sample is sieved to separate each size larger than the 9.5 mm ($^3/_8$ in.) Sieve. Each size is then tested in a proportional caliper device by setting the caliper to the longer dimension and attempting to fit the smaller dimension of the particle through the other caliper gap, which is a prescribed ration smaller then the larger dimension (i.e., a 5:1 ration). Particles are counted or weighed to determine a percentage of flat, elongated, or flat and elongated particle in a sample. Superpave specifications require asphalt mixtures to have less than 10% flat and elongated particles using a 5:1 ration.

Common Testing Errors

Not obtaining a representative sample.

Not reducing the sample properly.

Not sieving to completion.

Improper positioning in the machine.

TESTING METHODOLOGY

Apparatus

The following apparatus is needed to perform the test for flat and elongated particles:

- Proportional Caliper Device.
- Balance - Accurate to 0.5% of the mass of the sample.
- Oven or hot plate (if determination is made by mass).

Note: *If the proportional caliper is not used, the degree of error could increase dramatically.*

Sampling

Sample the coarse aggregate in accordance with AASHTO T 2. Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in AASHTO T 248.

Sample Size

Set up the test sample according to the following table:

If Maximum Size of the Material is: (retained on)	Then Split Out:
9.5 mm ($^3/_8$ in.)	1 kg (2 lb.)
12.5 mm (½ in.)	2 kg (4 lb.)
19.0 mm ($^3/_4$ in)	5 kg (11 lb.)
25.0 mm (1 in.)	10 kg (22 lb.)
37.5 mm (1 ½ in.)	15 kg (33 lb.)

Note: This is the entire sample (+4 and -4). Put it in the appropriate size pan (or bag) as needed. It will then be sieved out by size. Mark the work sheet as “Flat and Elongated Particles”. (Only test the sizes that are present in the amount of 10% or more of the original sample, in other words the gradation needs to be completed first.)

Test Procedure

1. If determination by mass is required, oven dry the sample to a constant mass at a temperature of 110°∓5° C. If determination is by particle count, drying is not necessary.

2. Sieve the sample of coarse aggregate to be tested in accordance with test method AASHTO T 27. Reduce each size fraction larger than the 9.5mm(d in.) sieve that is present in the amount of 10% or more of the original sample in accordance with method AASHTO T 248 until approximately 100 particles are obtained.

3. Use the proportional caliper device positioned at the 5:1 ratio.

4. Set the larger opening equal to the particles longest dimension. The particle is considered flat and/or elongated if the particles thinnest dimension passed through the smaller opening.

5. Test each of the particles in each size fraction and place in one of two groups: (1) Particles with longest to thinnest ratios over 5:1 and (2) Particles with longest to thinnest ratios less than 5:1.

Checking Elongation

Checking Flatness

6. After particles have been classified into the two groups, determine the proportion of the sample in each group by either count or by mass as required.

Calculation

Calculate the percentage of flat and elongated particles to the nearest 1% for each sieve size greater the 9.5mm(d in.).

Note: *Follow the rounding rules specified by your state.*

Example Calculation

19.0 mm ($^3/_4$ in) Stone

Sieve	25.0 mm	19.0 mm	12.5 mm	9.5 mm
% Passing	100	99.4	75.7	46.4
% Retained	0	0.6	23.7	29.3

No test is performed on the 19.0 mm size aggregate because it is less than 10 percent of the total sample. It will be assumed that the 19.0 mm particles have the same percentage of flat and elongated as the next sieve (12.5 mm).

The 12.5 mm size material totaled 715.3 grams after reducing to approximately 100 particles. 6.9 grams were classified as flat and elongated, therefore, the percent flat and elongated on the 12.5 mm sieve is:

$$\frac{6.9}{715.3} \times 100 = 1.0\%$$

Likewise, the 9.5 mm size totaled 239.7 grams after reduction and 12.2 grams were classified as flat and elongated. The percent flat and elongated on the 9.5 mm sieve is:

$$\frac{12.2}{239.7} \times 100 = 5.1\%$$

The percentage of flat and elongated particles on each sieve is reported to the nearest whole percent.

To calculate the weighted average percent flat and elongated particles for the sample, the percentage calculated for each individual sieve needs to be multiplied by the ratio of the percent retained for that sieve to the total percent retained above the 9.5 mm sieve and the results totaled for all sieves.

The total percent retained for the example is 53.6%. The percent flat and elongated on the 19.0 mm sieve is assumed to be 1.0% (same as the 12.5 mm size). The percent retained on the 19.0 sieve is 0.6%, therefore, to calculate the weighted average percent:

$$(1.0)\ \frac{0.6}{53.6} = 0.0\%$$

For the 12.5 mm sieve the weighted average percent is:

$$(1.0)\ \frac{23.7}{53.6} = 0.4\%$$

And for the 9.5 mm sieve the weighted average percent is:

$$(5.1)\ \frac{29.3}{53.6} = 2.8\%$$

Finally, the weighted average percent flat and elongated particles in the coarse aggregate is determined by adding the weighted average percent for each sieve:

$$0.0 + 0.4 + 2.8 = 3.2\%$$

For reporting, round the result to the nearest whole percent.

FLAT AND ELONGATED PARTICLES (ASTM D 4791) WORKSHEET

Project Example Mix Design ID _____ Date _____

Material/Stockpile ID _____ Technician _____

Sieve Sizes	Original Percent Retained	Mass Tested grams	Mass Failing 5:1 ratio (g)	%Flat &Elong. Individual sieve	%Flat & Elong. Weighted Ave.
	A	**B**	**C**	**D**	**E**
37.5 mm (1 ½ in.)					
25.0 mm (1 in.)					
19.0 mm ($^3/_4$ in.)	0.6	NA	NA	1.0	0.0
12.5 mm (½ in.)	23.7	715.3	6.9	1.0	0.4
9.5 mm ($^3/_8$ in.)	29.3	239.7	12.2	5.1	2.8
Total % Retained	53.6				Total 3.2

Remarks: Example

Weighted average percent Flat & Elongated particles = 3%

FLAT AND ELONGATED PARTICLES (ASTM D 4791) WORKSHEET

Project _____ Mix Design ID _____ Date _____

Material/Stockpile ID _____ Technician _____

Sieve Sizes	Original Percent Retained	Mass Tested grams	Mass Failing 5:1 ratio (g)	%Flat &Elong. Individual sieve	%Flat & Elong. Weighted Ave.
	A	**B**	**C**	**D**	**E**
37.5 mm (1 ½ in.)	_____	_____	_____	_____	_____
25.0 mm (1 in.)	_____	_____	_____	_____	_____
19.0 mm ($^3/_4$ in.)	_____	_____	_____	_____	_____
12.5 mm (½ in.)	_____	_____	_____	_____	_____
9.5 mm ($^3/_8$ in.)	_____	_____	_____	_____	_____
Total % Retained	_____				Total _____

Remarks: _____

_____

_____

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

AASHTO T 304

Developed by
FHWA Multi-Regional Aggregates Training & Certification Group

July 1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T84, Specific Gravity of Fine Aggregates
- AASHTO T11, Materials Finer than 75µm (No. 200) Sieve by Washing.

Table of Contents

AASHTO T304, Uncompacted Void Content of Fine Aggregate

Scope

This method determines the loose uncompacted void content of a sample of fine aggregate. When performed on an aggregate sample of a known, standard grading (Method A), this measurement provides an indication of particle shape. The materials' angularity, roundness or surface texture relative to other materials of the same standard grading is indicated by the percent of voids determined by this test. The Superpave asphalt mix design method sets minimum requirements for void content that vary depending on traffic loads and depth from the surface of the asphaltic concrete pavement. In this method, the prepared sample is allowed to free-fall through a standard funnel of a specified diameter, from a specified height into a small cylinder of known volume (nominal 100 ml).

When performed on an "as received" sample (Method C), this method can serve as an indicator of the effect the fine aggregate can have on the workability of Portland Cement concrete.

> NOTE: This manual covers Test method A only.

The material is then leveled with the top of the calibrated cylinder and weighed. Because the volume and weight of the cylinder are known, the weight of the sample contained in the cylinder can be calculated. Using the Bulk Dry Specific Gravity (As determined by AASHTO T84), the volume of the material in the cylinder is calculated. By subtracting the calculated volume of material from the calibrated volume of the testing cylinder, the volume of voids can be calculated.

Summary of Test Method

A sample of sand is prepared in accordance with one of three methods. Method A, a standard gradation, is the most common used. The sample is allowed to free-fall from a funnel into a cylinder of known volume. Using the bulk dry specific gravity of the sample as determined by AASHTO T84, the percent of void space in the cylinder is calculated. This value is known as the Fine Aggregate Angularity Value or FAA.

Typical Test Results

Using Method A, values typically range between 35 to 43 for natural sands and from 43 to 50 for crushed products. Values are obtained from more than one test of the same sample.

Common Testing Errors

1. Improper calibration of test cylinder or damage to test cylinder resulting in a change in volume.
2. Vibration in test area resulting in over-compaction of sample in test cylinder.
3. Erroneous specific gravity used in calculation. A difference of 0.05 specific gravity can cause an error of 1.0-% FAA value.

Apparatus

- Cylindrical measure approximately 39 mm (1.56 in.) in diameter, 86 mm (3.44 in.) deep with a capacity of approximately 100-mL.
- Funnel conforming to figure 2 in AASHTO T304.
- Funnel Stand conforming to figure 2 in AASHTO T304.
- Glass Plate for calibrating cylindrical measure.
- Pan large enough to contain funnel stand and to catch overflow material.
- Metal spatula with a straight edge approximately 100 mm (4.0 in.) long and 20 mm (0.8 in.) wide.
- Balance accurate and readable to 0.1 grams.

Procedure – Only Method A will be covered in this procedure, for other methods consult AASHTO T304

1. Wash representative sample in accordance with T11. The size of this sample is dependent on the gradation of the sample. Generally 500 grams to 700 grams is sufficient to yield the necessary size fraction quantities.

2. Dry washed sample material in a 110+/- 5 ° C (230+/- 9 °F) oven to a constant weight.

Sieve material in accordance with AASHTO T27. Remove the following size fractions from the sieves and retain in separate, labeled containers:

Passing No. 8 – Retained on No. 16
Passing No. 16 – Retained on No. 30
Passing No. 30 – Retained on No. 50
Passing No. 50 – Retained on No. 100

3. Weigh individual size fractions and combine them in accordance with the following:

Size Fraction	Mass, grams
No. 8 X No. 16	44
No. 16 X No.30	57
No. 30 X No.50	72
No. 50 X No.100	17
Total	**190**

4. Mix combined sample thoroughly with spatula.

5. Place finger under opening in funnel to seal opening. Pour mixed sample into funnel.

Pouring sample into funnel

6. Quickly remove finger from funnel and allow sample to free-fall into the calibrated cylinder.

7. Take care not to vibrate or unnecessarily disturb the material in the cylinder to avoid further consolidation. Strike off the excess material above the lip of the cylinder with the spatula edge, held in a vertical position, using one continuous motion.

8. After striking off, remove any excess sand from the outside of the cylinder using a small brush. At this point, additional compaction of the material in the cylinder will not affect the test results and will aid in handling.

9. Weigh the cylinder with the sample and record to the nearest 0.1 grams. Retain and recombine all materials for the next trial.

Weighing the Cylinder

Calculate uncompacted voids content as follows:

$$U = \frac{V - (F / G)}{V} x100$$

Where:

V = Volume of calibrated cylinder in mL (cubic centimeters)

F = Net Mass of Sample in Cylinder (Gross mass minus mass of empty cylinder)

G = Bulk dry specific gravity as determined by AASHTO T84

U = Uncompacted Voids in Percent (reported to nearest 0.1%)

10. Repeat test using recombined sample. Calculate and report average of at least two trials.

Instructors Note: Experience has shown that variability in results decreases with operator experience and an increase in the number of trials performed. It is recommended that at least three trials be performed and that three consecutive results be checked against the single operator precision statement in AASHTO T304.

Example Calculations:

Natural Sand

Volume of Cylinder: 99.92 mL
F= 156.36gm.
G= 2.643

$$U = \frac{99.92 - (156.36gm. / 2.643}{99.92} \times 100 = 40.8$$

Manufactured Sand

Volume of Cylinder: 99.92 mL
F= 143.15
G= 2.862

$$U = \frac{99.92 - (143.15 / 2.862)}{99.92} \times 100 = 49.9$$

Quiz

1). Uncompacted voids is an indicator of.....
   a). The aggregates' surface texture.
   b). The roundness of the aggregate.
   c). The angularity of the aggregate.
   d). All of the above.

2). An error in specific gravity of 0.05 can effect the calculated voids result by as much as:
   a). 5.0%
   b). 1.0%
   c). 2.5%
   d). 10.0%

3). Vibration in the testing area will not effect the test results.
   True False

4). To calculate uncompacted voids the SSD specific gravity as determined in AASHTO T84 is used.
   True False

5). The calibrated volume of the Cylinder is not critical to the calculation.
   True False

GLOSSARY

Voids- Difference between the total volume and the volume occupied only by the aggregate particles. The amount of void space (or air space) is a function of the aggregate gradation, particle shape and texture, and the amount of compaction of the material.

Uncompacted Voids- The amount of void space present when the material is in an uncompacted, unconsolidated state.

Bulk Dry Specific Gravity- The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

Angularity- a description of the degree of roughness, surface irregularities or sharp angles of the aggregate particles (i.e. particle shape).